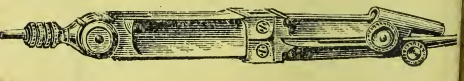
ELECTRICAL TABLES AND MEMORANDA.

THOMPSON AND THOMAS.



A HANDBOOK

OF

FORMULÆ, TABLES & MEMORANDA

FOR ARCHITECTURAL SURVEYORS AND OTHERS ENGAGED IN BUILDING.

By J. T. HURST, C.E.

Fifteenth Edition, thoroughly revised and enlarged.

Containing:

Formulæ and Tables for the Strength of Materials, Roofs, Water Supply, Drainage, Gas, and other matters useful to Architects and Builders—Information connected with Sanitary Engineering—Memoranda on the several Trades used in Building, including a description of Materials and Analyses of Prices for Builders' Work—The Practice of Builders' Measurement—Mensuration and the Division of Land—Tables of the Weights of Iron and other Building Materials—Constants of Labour—Valuation of Property—Summary of the Practice in Dilapidations—Scale of Professional Charges for Architects and Surveyors—Tables of English and French Weights and Measures.

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Dowson Taylor -
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2 Thickness. 2/4 ft [illegible]
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ELECTRICAL TABLES

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MEMORANDA

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or [illegible] [illegible] - [illegible]

Twice for double
if [illegible] [illegible] [illegible]

City of Lon Co.
Main Fuser
Tinned Strip
Copper —
$\frac{1}{2}$" wide say 200 a.

Small – 36 wk
reckoned 2 amps
each

Electrical Tables

and

Memoranda

by

SILVANUS P. THOMPSON

D.Sc., B.A., F.R.S.

and

EUSTACE THOMAS

London

E. & F. N. SPON, Ltd., 125 STRAND

New York

Spon & Chamberlain, 12 Cortlandt Street

1898

Fuse point

Take diameter of wire in inches, cube it, take root of result & multiply by 1642 — Result is current in amps. to fuse wire

CONTENTS.

—o—

Addendum to p. 17 of
ELECTRICAL TABLES.

Nos.	Total Width of Case.	Size of Groove.	Width of Centre Fillet.
	in.	in.	in.
1	$1\frac{1}{4}$	$\frac{7}{32}$	$\frac{3}{8}$
2	$1\frac{1}{2}$	$\frac{9}{32}$	$\frac{7}{16}$
3	$1\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{2}$
4	2	$\frac{7}{16}$	$\frac{1}{2}$
5	$2\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$
6	3	$\frac{5}{8}$	$\frac{7}{8}$
7	$3\frac{1}{2}$	$\frac{3}{4}$	1
8	4	1	1
9	5	$1\frac{1}{4}$	$1\frac{1}{4}$

J. F. & G. HARRIS.

Width of Grooves in J. F. & G. Harris's Casings.

See also Table facing page 1.

ELECTRICAL ENGINEERS' TABLES.

ELECTRIC LIGHTING DATA.

Incandescent Lamps of 16 candle-power may be considered as requiring 60 watts each: at 100 volts pressure they take 0 6 ampere; at 60 volts they take 1 ampere; at 50 volts 1·2 ampere per lamp. Each such lamp therefore takes about $\frac{1}{12}$ electric H.P., or about $\frac{1}{8}$ to $\frac{1}{9}$ I.H.P. One such lamp will light 60 to 100 sq. ft. floor space in ordinary rooms. Lamps of 8 to 10 candle-power take about half as much power.

Large Incandescent Lamps, of 100 to 1000 candle-power, are made under the name of "Sunbeam" lamps, for shops, entrance halls, &c. The power required to supply them may be taken about 1 indicated H.P. per 160 candles.

Arc Lamps may be estimated to require about 10 amperes at pressure of 55 volts; and need about 1 I.H.P. per lamp. The-

are, however, made for currents so low as 4 amperes, and for voltages down to 50. Ordinary arc lamps will not burn steadily at a lower pressure than 50 volts. The usual currents required are: Brush lamp, 10 amp.; Thomson-Houston, 10 amp.; Brockie-Pell, 12 amp.; Crompton (D.D.) 15 amp.; Maquaire, 6 amp.

Search Lights are special arc lamps of great power, requiring from 30 to 150 amp. at 55 volts. Require very large carbons, and are furnished with projecting lenses or mirrors.

Absorption of Light by Globes.—Clear glass is estimated to absorb about 10 per cent.; ground glass, 30 to 50 per cent.; opal glass, 50 to 60 per cent. of total light of the lamp.

Coal Consumption.—A good ordinary steam engine may be estimated to burn 6 to 12 lbs. of coal per horse-power-hour; large and condensing engines being more economical than small and non-condensing. Large engines, with double and triple expansion, are still more economical, and may require only $\frac{1}{3}$ of this amount per H.P.-hour.

Wires for Incandescent Lamps.—Allowing 1000 amperes per sq. inch of sectional area of copper—

1 No. 22 S.W.G. wire carries 0·6 amp., or 1 lamp at 100 volts pressure at mains.

1 No. 20 S.W.G. wire carries 1·0 amp., or 1 lamp at 60 volts pressure at mains.

1 No. 18 S.W.G. wire carries 1·8 amp., or 3 lamps at 100 volts pressure at mains.

1 No. 16 S.W.G. wire carries 3·2 amp., or 5½ lamps at 100 volts pressure at mains.

1 No. 14 S.W.G. wire carries 5·0 amp., or 8 lamps at 100 volts pressure at mains; 5 lamps at 60 ditto; 4 lamps at 50 ditto.

See *Special Wiring Tables*, pp. 18 to 33.

Temporary Resistances.

(1) For experimental work a resistance can be quickly made for large currents by using comparatively thin German silver or iron wire wound on a board and immersed in a tub of water.

(2) Two plates of copper, or of gas-carbon in a non-metallic vessel filled with water. Add acid drop by drop till resistance sufficiently low.

(3) Incandescent lamps in series or parallel.

Non-inductive Resistances.

For alternate-current working, coiled resistance wires are to be avoided, unless each coil is wound back on itself, so as to be non-inductive. Coiled wires, especially if with iron cores, act as *choking coils*, and impede as well as resist.

ELECTRIC LIGHT CIRCUITS.

Arrangements of circuits depend upon conditions of supply as to whether *pressure* is kept constant (as usual for glow-lamps), or whether *current* is maintained of invariable strength (as usual for arc lighting).

CIRCUITS FOR GLOW-LAMPS.

(A) DOMESTIC AND OTHER SMALL INSTALLATIONS.

1. *Simple Parallel Mains (Double Wiring).*—Out-going and return mains kept side by side, with branches and sub-branches, each consisting of two wires side by side under casing; all lamps simply joined across from the positive to the negative wire. Most usual system for house and hotel wiring for incandescent lamps. For case where accumulators are used, see p. 12.

2. *Separated Mains.*—In factory wiring it is often preferred to keep the positive and negative mains far apart running along opposite sides of shed or gallery. Each lamp has separate thin wire coming from one main, and another wire to the other main. In this case wires do not run side by side:

and there are no branches and sub-branches. This method is far less liable to leakages and short-circuits, but requires a little more wire than preceding. On this method, wood casings are sometimes dispensed with, the thin wires being run on insulators.

3. *Single Wire System.*—Sometimes, in ship lighting, one main only with branches and sub-branches is used, the metal of the ship being used as a common return or "earth." This wiring is decidedly less costly than double wiring, but there is much more danger of faults occurring; and the currents perturb the ships' compasses more. Experience shows this system to be unsatisfactory, as it is impossible to prevent the insulation from deteriorating by damp and other causes. (Abandoned in the Navy.)

4. *Multiple Series.*—Instead of single lamps being connected from positive to negative main, groups of 2, 3, or more lamps are joined in series, and the row is then connected across the mains. For example, instead of one 100-volt lamp of 16 candle-power, there may be used two 50-volt lamps of 8 candle-power. For house lighting there is no advantage however in this system, one drawback to which is that the breakage of any lamp causes the extinction of all others in that row. It has, however, been extended to—

(B) FACTORY AND EXHIBITION LIGHTING, and to other installations where all the lamps burn for an equal time, or where large groups only are switched in and out at one time. In one installation each row consisted of 50 25-volt lamps in series across mains at 1250 volts, there being as many of these rows in parallel with one another as the dynamo can safely supply current for. This (5) is therefore a *high-pressure system*, and effects great economy in mains. It is impossible, however, for economical working, to turn out fewer than 50 lamps at a time, and each lamp must have an *automatic guard* or *cut-in* (usually consisting of two copper disks with paraffined paper between) placed as shunt across its terminals to short-circuit the holder if the lamp breaks.

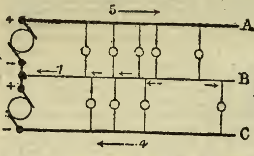
6. *Arc Lamps in Low-Pressure Circuits.*—Arc lamps are sometimes run (along with glow-lamps, or separately) on a low-pressure circuit (60 to 120 volts), a resistance wire being placed in the circuit of each arc to steady its burning. On circuits of 100 or more volts two arcs may be run in series, but in such case a powerful electro-magnet (rather than a mere resistance wire) should be placed in circuit with them. Such an electromagnet may be made by taking as core a thick ring coil of iron wire (say 9 inch

diam., and 2 or 3 inches thick, of No. 16 S.W.G.), and winding it like a Gramme ring with say 200 turns of No. 13 or 14 S.W.G. double-cottoned copper wire. Two arc lamps can thus be commercially worked in series across an alternate-current circuit at 90 volts pressure,

(C) CENTRAL STATIONS (and other installations for lighting extended areas).

7. *Three-Wire System.*—Not much employed except for large installations for central supply. Connections as in Fig. 1.

FIG. 1.



The outer main conductors A and C are of a size to carry the current required by half the total number of lamps only; the intermediate main B being usually smaller. If more lamps are burning between A and B,

than between B and C, the excess current (1 lamp in the Fig.) flows along central wire. Hopkinson employs two dynamos.

8. *Network, with Feeders.*—This is a variety of method (1) only used in large installations. The parallel mains, with their branches, constitute a network. Pairs of feeding mains may be carried direct from dynamos at the central station to distant points of the network, so that if during time when there is a great consumption at any part of the system, the potential at any part tends to drop, it may be kept up by sending currents down the feeders at a higher potential than that of the mains.

9. *Accumulator System.*—In certain cases accumulators are used. a large number of cells being charged in series from dynamos; the distributing mains to lamps being connected across smaller groups of the set. For example, current may be supplied at about 450 volts to a row of about 200 cells, situated at a sub-station, whence four sets of 100-volt circuits go to neighbouring consumers. In another method of arranging accumulators the cells that supply the lamps are periodically connected, at the central station, to the charging mains.

10. *Transformer System.*—In cases where alternating currents are supplied to a dis-

tance at a high pressure, transformers are used to transform the currents down to low pressure to suit the lamps. When lamps are to be fed at constant pressure, the transformers must be connected in parallel across the system of high pressure mains, the terminals of which (at the primaries of the transformers) must be kept at a constant (high) pressure. *There is no advantage in using alternating currents if the supply has not to be carried to great distances.* The low-pressure (secondary) circuits of the transformers may be arranged in simple parallel, or on a network system, or on a modified three-wire system. For very extended areas, currents are sometimes transmitted at a very high pressure, such as 5000 volts, to *sub-stations*, where they are transformed down to a lower pressure, such as 1000 volts, and thus distributed to small transformers at consumers' houses, which transform current down to 50 volts to supply the lamps. Nothing over 150 volts should ever be allowed inside a dwelling-house.

CIRCUITS FOR ARC LAMP LIGHTING.

11. *Simple Series.*—One wire going to all lamps in succession, and finally returning

to the dynamo. This is universally used for arc light systems such as those of Brush, Thomson-Houston, and Ball. Lamps must be provided with automatic cut-outs that failure of one lamp does not extinguish all others in the circuit. It necessitates high voltages, reckon 50 volts per arc lamp, and 50 volts per mile of line.

12. *Glow-Lamps in Arc Lamp Circuits.*—Bernstein and others make low-resistance glow-lamps to carry the same current as an arc lamp, so that they may be inserted in the circuit. These lamps are turned off by short-circuiting them; and each must be provided with an automatic guard or *cut-in*, in case the lamp breaks. Edison's "Municipal" lamp is a low resistance lamp for such uses.

13. *Branched Series.*—Sometimes a group of 10 or 12 or more glow-lamps in parallel is inserted in an arc-lamp circuit, or two such groups are arranged in series with one another. Each lamp to have an automatic guard. Neither method 12 or 13 is used in domestic lighting, on account of the high pressures employed, and consequent danger.

14. *Simple Parallel.*—Gulcher has used this system for running arc lamps on constant pressure mains at 65 volts. It necessitates very thick copper mains, and is not much used.

15. *Series Transformer System.*—When an alternating current is supplied from a special dynamo giving currents of invariable strength, transformers may be introduced, having their primary wires all in series in the circuit. Their secondary wires will then yield alternating currents also of constant strength, and may be used either with arc lamps or with incandescent lamps grouped in series with one another. Each group will be independent of other groups.

CIRCUITS FOR TOWNSHIP LIGHTING.

16. For lighting village streets and narrow thoroughfares in towns, glow lamps are more suitable than arc lamps. They should be arranged in series, or else in a split circuit (Parfitt's system) provided with protecting automatic devices. When very high voltages (exceeding 1000 volts) are used, simple cut-outs of paraffined paper between two metal disks suffice to protect the circuit, each lamp having one such cut-out.

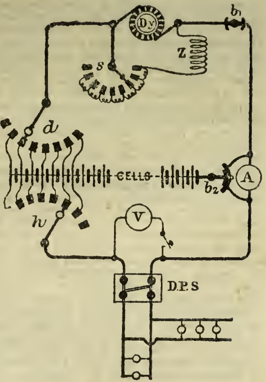
SPECIAL DOMESTIC CIRCUIT.

FOR SUPPLY WITH ACCUMULATORS.

(See Accumulators, p. 93.)

Accumulators may be used with any of the first eight systems of circuits, provided proper arrangements are adopted to ensure their regular charge and discharge. For a small installation, the best method of arranging circuits is shown in Fig 3. The cells are joined in a row, the last half dozen cells having additional connections to the contact blocks of the two regulating switches *d* and *h* on the switch board. The regulator *h* controls the pressure at which the current flows to the house-circuit when supplied from accumulators; the regulator *d* controls the number of cells charging from the dynamo. By altering the position of *d*, the reserve cells, which are the least used, need never be overcharged, even when dynamo and accumulators are working together. When the steam engine is governed for constant speed, the variable resistance *s*, which is in the exciting circuit of the field-magnets (the

FIG. 3.



coils of which, Z, are connected in shunt, is a necessity. It is advisable, however, to remove (or over-set) the governor, and keep up constant steam pressure. The engine will then automatically adjust its speed in such a way as to keep the current through its armature constant without altering *s*. This method is found very satisfactory in practice. A is an ampere-meter, V a voltmeter; b_1 and b_2 are switches. Of these b_2 is a special two-way switch, which permits the lower end of the row of cells to be connected at will either to the house-circuit or to the dynamo-circuit, *or to both at once*. When in this last position—which is the habitual one—the ampere-meter is short-circuited. By turning it in one way or the other the respective currents in the dynamo and house-circuits can be successively observed. Without this arrangement two separate ampere-meters would be needed. If desired to throw off the accumulators, and use dynamo alone, *d* must be shifted till it is directly connected to same cell as *h*; the engine governor being employed, and *s* suitably varied. The ampere-meter plug having been inserted, the switch b_2 may then be turned right off. The ampere-meter should be of a pattern which shows both strength and direction of current. The switches *d* and *h* must be so constructed as

not to short-circuit the cells between successive contact blocks, in moving from one to the other.

D.P.S. is the main switch, preferably double-pole. The necessary cut-outs are not shown.

Measurement of Very Large Currents.

Very large currents may be measured by ascertaining with a low-reading voltmeter the drop of potential they produce in some conductor of small known resistance, such as one or more strips of platinoid. Calculate current by dividing drop of voltage by resistance of strip.

Rough Measurement of High Potentials.

The voltage of an unknown transformer or alternate current dynamo may be ascertained by joining across its terminals as many glow lamps as can be properly incandesced. From the number of lamps, and voltage of each, the whole potential may be ascertained.

Considerations that Determine Size of Conductors.

1. *Fire Office Rules* must be taken as the guide for determining the proper gauge of wire to employ *in all those cases* where the conductors are as *short* as in the wiring of ordinary houses, shops, hotels, &c.; that is, the gauge is determined solely by the current which the wire can carry without risk of overheating. See *Fire Office Rules*, p. 53.

2. Fire Office Rules do *not* determine the size of wires in those cases where *long* conductors are carried in sunken conduits or in overhead cables, to maintain a given voltage at the lamps. In these cases the proper gauge to employ is determined by the permissible drop of potential. See following Table, p. 18, and Example on p. 28.

3. For conductors for Transmission of Power, where the line is long and costly, the size is determined by the conditions of maximum economy.

4. *Law of Maximum Economy* (Sir Wm. Thomson). If cost of cable, labour of erecting, &c., is proportional to its weight, then

the greatest economy will be obtained when that cost is such that:—Interest on capital expenditure = the annual cost of electric energy wasted in the line. The initial condition is not generally fulfilled however, making the law inapplicable; in which case Forbes's modification must be used. See Kapp's *Transmission of Energy*, p. 93.

WIDTH OF GROOVES IN J. F. & G. HARRIS'S CASINGS.

Casing.	Width of Groove.	Width of Fillet between Grooves.
	in.	in.
A	$1\frac{1}{4}$	$1\frac{1}{2}$
B	1	$1\frac{1}{2}$
C	$\frac{3}{4}$	1
D	$\frac{5}{8}$	1
E	$\frac{1}{2}$	1
F	$\frac{3}{8}$ full	1
G	$\frac{3}{8}$ less	1
H	$\frac{5}{16}$	$\frac{5}{8}$
I	$\frac{1}{4}$	$\frac{1}{2}$
K	$\frac{3}{16}$	$\frac{1}{2}$

This table is calculated for copper of 98 per cent. conductivity taken as 555 lbs. per cubic foot. The specific resistance of copper microhms per cm. cube. The *resistance*, and the *permissible* material by multiplying the values in the respective columns by referred to pure copper.

S.W.G.	Diameter.				Area of Conductor.	
	Each Wire.		Cable.			
	inch.	mm.	inch.	mm.	Sq. inch.	Sq. mm.
20	·036	·914	..	..	·00102	·658
19	·040	1·014	..	..	·00126	·813
18	·048	1·219	..	..	·00181	1·168
3/22s	·028	·711	..	..	·00186	1·193
7/25s	·020	·508	·060	1·524	·00217	1·418

TABLE (at 60° Fahr.).

for a temperature of 60° Fahrenheit. The density of copper is for the above temperature and conductivity is taken as 1·729 *current at* 1000 *amps. per square inch,* may be found for any other $\frac{98}{m}$ and $\frac{m}{98}$ respectively; where m is the percentage conductivity

Weight per Foot. lbs.	Resistance per Foot. Ohms (legal).	Current at 1000 Amps. per Sq. In.	k
·00393	·008007	1·02	122
·00486	·006480	1·26	151
·00698	·004510	1·81	217
·00751	·004417	1·86	223
·00836	·003716	2·17	260

S.W.G.	Diameter.				Area of Conductor.	
	Each Wire.		Cable.			
	inch.	mm.	inch.	mm.	Sq. inch.	Sq. mm.
17	·056	1·422	..	..	·00246	1·587
7/24s	·022	·559	·066	1·677	·00266	1·716
7/23s	·024	·610	·072	1·830	·00315	2·043
16	·064	1·626	..	..	·00322	2·077
15	·072	1·828	..	..	·00407	2·625
7/22s	·028	·711	·084	2·133	·00434	2·781
7/21½s	·030	·762	·090	2·28	·0050	3·242
14	·080	2·028	..	..	·00503	3·245
7/21s	·032	·813	·096	2·439	·00560	3·631
7/20½s	·033	·838	·099	2·51	·0061	3·923
13	·092	2·336	..	..	·00665	4·289
7/20s	·036	·914	·108	2·742	·00714	4·606

TABLE—*contd.*

Weight per Foot. lbs.	Resistance per Foot. Ohms (legal).	Current at 1000 Amps. per Sq. In.	k
·00948	·003319	2·46	295
·01025	·003070	2·66	319
·01214	·002579	3·15	378
·01241	·002536	3·22	386
·01569	·002007	4·07	488
·01673	·001894	4·34	521
·01927	·001634	5·00	600
·01938	·001624	5·03	604
·02158	·001451	5·60	672
·02350	·001332	6·10	732
·02563	·001228	6·65	798
·02752	·001144	7·14	857

S.W.G.	Diameter.				Area of Conductor.	
	Each Wire.		Cable.			
	inch.	mm.	inch.	mm.	Sq. inch.	Sq. mm.
12	·104	2·641	..	..	·00849	5·476
7/19s	·040	1·014	·120	3·042	·00882	5·691
11	·116	2·946	..	..	·0106	6·837
7/18s	·048	1·219	·144	3·657	·0127	8·176
10	·128	3·251	..	..	·0129	8·322
9	·144	3·658	..	..	·0163	10·52
7/17s	·056	1·422	·168	4·266	·0172	11·10
19/20s	·036	·914	·180	4·570	·0194	12·50
8	·160	4·063	..	..	·0201	12·96
7/16s	·064	1·626	·192	4·878	·0225	14·54
19/19s	·040	1·014	·200	5·070	·0239	15·45
7	·176	4·470	..	..	·0243	15·68

TABLE—*cont*

Weight per Foot. lbs.	Resistance per Foot. Ohms (legal).	Current at 1000 Amps. per Sq. In.	k
·03272	·000962	8·49	1,019
·03399	·000926	8·82	1,058
·04085	·000771	10·6	1,272
·04895	·000645	12·7	1,524
·04972	·000633	12·9	1,548
·06282	·000501	16·3	1,956
·06628	·000475	17·2	2,064
·07476	·000422	19·4	2,328
·07747	·000406	20·1	2,412
·08672	·000362	22·5	2,700
·09210	·000341	23·9	2,868
·09365	·000336	24·3	2,916

S.W.G.	Diameter.				Area of Conductor.	
	Each Wire.		Cable.			
	inch.	mm.	inch.	mm.	Sq. inch.	Sq. mm.
7/15s	·072	1·828	·216	5·484	·0285	18·38
6	·192	4·876	..	..	·0290	18·71
19/18s	·048	1·219	·240	6·095	·0344	22·19
7/14s	·080	2·028	·240	6·084	·0352	22·72
19/17s	·056	1·422	·280	7·110	·0467	30·15
19/16s	·064	1·626	·320	8·130	·0612	39·46
19/15s	·072	1·828	·360	9·140	·07 3	49·88
19/14s	·080	2·028	·400	10·14	·0956	61·66
37/16s	·064	1·626	·448	11·38	·119	76·85
19/13s	·092	2·336	·460	11·68	·126	81·49
37/15s	·072	1·828	·504	12·80	·151	97·13
19/12s	·104	2·641	·520	13·21	·161	104·0

TABLE—*contd.*

Weight per Foot. lbs.	Resistance per Foot. Ohms (legal).	Current at 1000 Amps. per Sq. In.	k
·1098	·000287	28·5	3,420
·1118	·000282	29·0	3,480
·1326	·000237	34·4	4,128
·1356	·000232	35·2	4,224
·1800	·000174	46·7	5,604
·2359	·0001336	61·2	7,344
·2980	·0001056	77·3	9,276
·3684	·0000855	95·6	11,472
·4585	·0000686	119	14,280
·4856	·0000647	126	15,120
·5820	·0000543	151	18,120
·6204	·0000507	161	19,320

S.W.G.	Diameter.				Area of Conductor.	
	Each Wire.		Cable.			
	inch.	mm.	ineh.	mm.	Sq. inch.	Sq. mm.
37/14s	·080	2·028	·560	14·20	·186	120·1
37/13s	·092	2·336	·644	16·35	·246	158·7
37/12s	·104	2·641	·728	18·49	·314	202·6
					·400	258
					·500	323
					·600	387
					·700	452
					·800	515
					·900	581
					1·000	645

TABLE—*contd.*

Weight per Foot. lbs.	Resistance per Foot. Ohms (legal).	Current at 1000 Amps. per Sq. In.	k
·7168	·0000475	186	22,320
·9479	·0000332	246	29,520
1·210	·0000260	314	37,680
1·542	·0000204	400	48,000
1·927	·0000163	500	60,000
2·313	·0000136	600	72,000
2·698	·0000117	700	84,000
3·083	·0000102	800	96,000
3·468	·00000907	900	108,000
3·854	·00000817	1000	120,000

Drop of Potential.

To find the cable to employ when a current of i amperes is carried, with a fall of potential of v volts, the total length of cable being l feet.

Rule.—Multiply the current by the length of cable in feet, and divide by the lost volts. Call the result k. Opposite the value of k which is nearest to this in the foregoing table, is the size of conductor to be employed, and the current it will carry at 1000 amps. per sq. in.

$$k = \frac{i \times l}{v}.$$

Example.—Current, 30 amperes; length of cable, 700 feet; lost volts, 5.

$$k = \frac{30 \times 700}{5} = 4200.$$

The size of cable corresponding to 4200 for k is a 7/14s.

If a conductor of other material than copper be employed, the value of k obtained above must be multiplied by $\frac{98}{m}$, (where m is the percentage conductivity) and the corresponding size of cable looked out.

To find the volts lost in a given cable, multiply the current by the length in feet, and divide by the value of k opposite the size of cable.

Example: A 19/19s cable is 1000 feet long, and carries 35 amperes; find the lost volts.

k, for a 19/19s conductor, is 2868.

$$\therefore\ v = \frac{35 \times 1000}{2868} = 12 \text{ volts.}$$

Note.—If the figure in the last column but one is greater than the current to be transmitted, the current density is *less* than 1000 amps. to the square inch. If the figure be less, *more* than 1000 amps. per square inch are being transmitted.

Alternating Volts.

In alternate current systems voltage cannot be measured by ordinary voltmeters. Either hot-wire voltmeters (such as Cordew's) or electrostatic voltmeters (such as Lord Kelvin's multicellular instrument) must be used. The readings give *virtual* volts, i. e. volts averaged according to the square root of the mean squares of the values from moment to moment.

Diameters and Weights of Silvertown Electric Light Cables.

S.W. Gauge.	Class D.		Classes J, Q, K, & S. 300 & 600 Megs.		Class L. 5000 Megs.		Classes W and X.	
	Diam.	Wt. per ft.	Diam.	Wt. per ft.	Diam.	Wt. per ft.	Diam.	Wt. per ft.
20	..	..	·173	·018	..	..	·144	·012
19	..	..	·177	·019	..	..	·148	·013
18	..	..	·187	·023	..	..	·156	·016
3/22s	..	..	·199	·026	..	..	·167	·017
7/25s	..	..	·200	·027	..	..	·168	·018
17	..	..	·196	·027	..	..	·164	·019
7/23s	..	..	·214	·033	..	..	·180	·023
16	..	..	·203	·030	..	..	·172	·022
15	..	..	·214	·036	..	..	·180	·027

S.W. Gauge.	Class D.		Classes J, Q, K, & S. 300 & 600 Megs.		Class L. 5000 Megs.		Classes W and X.	
	Diam.	Wt. per ft.	Diam.	Wt. per ft.	Diam.	Wt. per ft.	Diam.	Wt. per ft.
7/22s	..	..	·228	·040	..	..	·192	·029
14	..	..	·224	·041	..	..	·188	·031
7/21½s	..	..	·236	·044	..	..	·198	·032
7/20½s	..	..	·246	·049	..	..	·207	·036
13	..	..	·238	·049	..	..	·200	·038
7/20s	·225	·046	·300	·070	·304	·068	·211	·044
12	..	..	·252	·059	..	..	·212	·046
7/19s	·237	·054	·318	·081	·318	·080	·233	·052
11	..	..	·269	·070	..	..	·224	·055
7/18s	·261	·072	·350	·105	·369	·108	·257	·070
10	..	..	·284	·081	..	..	·236	·065

Diameters and Weights of Cables—*contd.*

S.W. Gauge.	Class D.		Classes J, Q, K, & S. 300 & 600 Megs.		Class L. 5000 Megs.		Classes W and X.	
	Diam.	Wt. per ft.	Diam.	Wt. per ft.	Diam.	Wt. per ft.	Diam.	Wt. per ft.
9	..	..	·305	·099	..	..	·252	·080
7/17s	·285	·093	·382	·132	·412	·139	·281	·090
19/20s	·297	·103	·400	·145	·434	·153	·293	·100
8	..	..	·327	·118	..	..	·268	·096
7/16s	·309	·117	·415	·162	·455	·174	·305	·113
19/19s	·317	·123	·426	·170	·470	·184	·313	·120
7/15s	·333	·143	·447	·197	·499	·214	·329	·139
19/18s	·357	·169	·479	·230	·542	·252	·353	·165
7/14s	·357	·172	·479	·234	·542	·257	·353	·167
19/17s	·397	·223	·530	·296	·614	·331	·393	·218
19/16s	·437	·284	·590	·337	·686	·422	·433	·276

Diameters and Weights of Cables—*contd.*

S.W. Gauge.	Class D.		Classes J, Q, K, & S. 300 & 600 Megs.		Class L. 5000 Megs.		Classes W and X.	
	Diam.	Wt. per ft.	Diam.	Wt. per ft.	Diam.	Wt. per ft.	Diam.	Wt. per ft.
19/15s	·477	·353	·650	·469	·758	·523	·473	·346
19/14s	·517	·429	·710	·570	·830	·635	·513	·421
37/16s	·565	·528	·782	·699	·916	·778	·561	·520
19/13s	·577	·557	·800	·740	·938	823	·573	·548
37/15s	·621	·659	·866	·873	1·017	·971	·617	·650
19/12s	·631	·701	·890	·933	1·046	1·036	·633	·692
37/14s	·677	·806	·950	1·065	1·118	1·184	·673	·795
37/13s	·761	1·052	1·076	1·387	1·269	1·543	757	1·041
37/12s	·845	1·332	1·202	1·759	1·420	1·946	·841	1·289
61/13s	·945	1·708	1·352	2·247	1·600	2·490	·941	1·693
61/12s	1·053	2·167	1·514	2·848	1·795	3·056	1·049	2·150

Class D is meant for running on insulators, or to be suspended from a steel wire. Insulation — two coatings of braided tarred flax.

Classes J, K, and L. Pure indiarubber, then vulcanising indiarubber; indiarubber-coated tape, and the whole vulcanised together. BRAIDED tarred flax, and coated preservative compound. *Wires from* 7/20s.

Classes Q and S. Insulated pure, and vulcanising indiarubber; indiarubber-coated tape; the whole vulcanised together, then BRAIDED cotton and covered preservative compound. *Wires up to* 7/20½s.

The weights and diameters of J and K and of Q and S are practically the same, and they have been put together.

JOINTING.

A. *Straight Joint:* Cable to Cable.

(1) Pare off the insulation in separate layers, as shown in Fig. 1, so as to leave a length of cable exposed, equal to about 10 diameters (shown too short in all the drawings to save space). It is very necessary that a fair length of clean indiarubber should be left at *a*.

(2) Cut out all but the outside wires for 4 diameters; leaving the central wire or

wires short, as shown at *b*, Fig. 1, only shorter than shown.

(3) *Carefully clean*, and if needful tin, all separate wires that are to be joined.

FIG. 1.

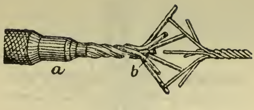


FIG. 2.

(4) Put the two cables together, interlacing the wires, and twist up as in Fig 2; this is to be done as tightly as possible with aid of gas pliers.

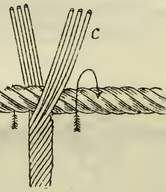
(5) *Soldering.*—This may be done with an iron; or preferably, if joint large, by pouring solder over it, as in wiping a plumbers' joint.

Flux: Resin, or resin with neats' foot oil. *No acid or spirits, on any account.*

B. *Straight Joint:* Single Wire to Cable. Some of the heart wires of cable cut out; single wire, previously cleaned and tinned, inserted in their places. The whole then twisted up tight, and the joint well soldered.

C. *T-Joint*: Cable to Cable (first method). Figs. 4 and 5 explain themselves. The ends

FIG. 4.



cc should be left as long as 4 to 6 times diameter of larger cable.

D. *T-Joint*: Cable to Cable (second method). The large cable is first split, and

small cable, flattened somewhat, is passed through (Fig. 6), and its ends then divided and wrapped round and soldered.

FIG. 5.

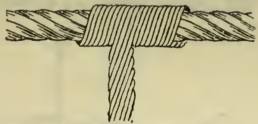
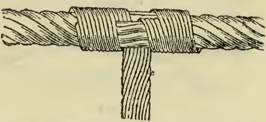


FIG. 6.



E. *T-Joint*: Single Wire to Cable. Wrapped round 2 or 3 times and soldered.

F. *Joints in Single Wires.*—Best forms are shown in Figs. 7, 8, 9, and 10. In Fig. 9 (Rousseau's joint) the thin side wire A is

FIG. 7.

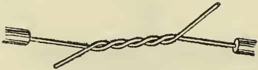
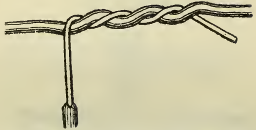


FIG. 8.



wrapped at B C, around the thicker wire. Another piece of wire, E D, of the same gauge as A is then wrapped on, partly over A, partly over the thick wire. beginning at the middle and ending at E and D. The whole is soldered.

Fig. 9.

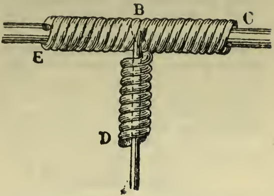


Fig. 10, the *Britannia Joint*, is used where the wires are subjected to mechanical stress as in aerial conductors.

Fig. 10.

N.B.—As heating the wires greatly lessens their strength, soldering should be done at

as low a temperature as possble, wherever the joint is required to be as strong as possible.

Essentials for good Soldering. — Careful cleaning of all wires to be joined and (except in the case above) *hot* irons or solder. As heating the wires is apt to make them rather brittle, it is an excellent plan to make the smaller joints rather longer, and to solder only in the middle. A turn or two of thin binding wire may be necessary at the ends.

See that the insulation is cut back so far as not to be injured in the act of soldering.

Covering Joints.

1*st Method*. Suitable for large joints—

1. Take off all sharp points of wire or solder on part to be covered.

2. Cover joint up to, *but not over*, the indiarubber with indiarubber covered tape.

3. Layer of hot (but not burning) Chatterton compound *joining well* on to indiarubber.

This layer must be well worked round, and completely cover the underlying tape.

4. One or two layers of tape, tarred or indiarubber covered.

Note.—It is preferable at times to make 3 and 4 rather thin, and add second layers of Chatterton and tape. The first layer of tape is frequently omitted.

2nd Method. Most suitable for small joints—

1. Indiarubber covered tape up to indiarubber.

2. Indiarubber strip backwards and forwards, up to and over indiarubber of cable, with indiarubber solution between layers.

Note.—The insulating materials should not be touched with *wet* fingers when any gaps are visible.

BINDING TO INSULATORS.

Terminal wires are always attached to shackles, in the way shown in Fig. 11.

FIG. 11.

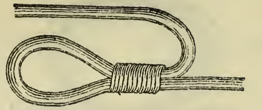
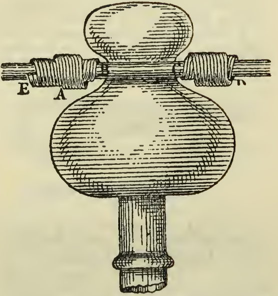


Fig. 12. *A doubled* binding wire starts at A, leaves the *top* of the conductor at B, passes tightly round the back of the insulator to the bottom of the conductor at C. It is continued to D, then passes back to C, round the insulator to the *bottom* of the conductor at B, and is continued on to E.

FIG. 12.



AERIAL CONDUCTORS.

Wires supported on insulators are stretched as tightly as their strength will allow. The

wire is stretched until the dip has the value indicated by the following formula:

$$d = \frac{W S^2}{8 b}. \qquad (1)$$

The following are also useful:

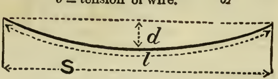
$$l = S + 2{\cdot}67 \frac{d_2}{S}. \qquad (3)$$

$$d = \sqrt{{\cdot}375 S (l - S)}. \qquad (2)$$

Where

S = span.
l = true length of wire.
d = dip of wire.
W = wt. of 1 ft. of wire.
b = tension of wire.

See sketch.



b is usually taken as $\frac{1}{3}$ the weight which will break the wire. For the *same material* the dip is the same whatever the gauge of wire employed, since W and b increase practically proportionally.

In cold weather the wire contracts, the dip becomes less, and the tension to which the wire is subjected greater. As it is very

necessary that the tension should never exceed that for which the dip is calculated above, (1), wires put up in warm weather must not be stretched so tightly as in cold weather.

In places where heavy falls of snow are probable, a larger factor of safety than the above should be allowed.

The breaking stress and conductivity of wire varies very greatly with different manufacturers, and should always be ascertained before ordering.

This is very noticeable in silicium bronze, the conductivity of which varies greatly with the tensile strength.

Hard-drawn copper wires suitable for aerial telephone or telegraph lines weigh from 100 to 200 lb. per statute mile. The wire weighing 100 lb. per mile is 79 mils. in diam., breaks with 330 lb. pull, and has resistance 9·1 ohms per mile. The wire weighing 200 lb. is 112 mils. thick, breaks at 650 lb., and has 4·53 ohms resistance per mile.

Galvanised iron wires are used only in telegraphy, or for *short* telephone lines. For all electric light purposes, and for fast-speed telegraphy and long-distance telephony, copper must be employed.

Data for Aerial Conductors.

Material.	Breaking Stress, lbs. per sq. in.	Working Stress, lbs. per sq. in.	Conductivity.	K
			percent.	
Copper, hard drawn	63.000	21,000	98	·0000229
Iron, ordinary ..	50,000 to 64,000	17.000 to 23,000	13 to 16	·0000250 to ·0000210
Steel	120.000 to 300.000	40.000 to 100,000	13	·0000104 to ·0000042
Phosphor bronze ..	100.000 to 150.000	33,000 to 50,000	27	·000013 to ·000009
Silicium bronze (A)	67.000	22,000	96	·0000216
,, (B)	78.000	26,000	80	·0000186
,, (C)	110.000	37 000	42	·0000132

K, in the last column, is the constant $\frac{W}{8\,b}$. The dip is found by multiplying K by the span twice over. Thus: Material, phosphor bronze. Breaking stress, 100,000 lbs. per sq. in. Span, 500 feet. Dip $= 500 \times 500 \times \cdot 000013 = 3 \cdot 25$ feet.

Dip and Span Table for Iron Wire (Treuenfeld).

Breaking stress, assumed 53,000 lbs. per square inch. Working stress, ⅓ of this. This table is independent of the gauge of wire.

Span. Feet.	Dip.					
	Lowest Probable Temperature.	10° C. higher.	20° C. higher.	30° C. higher.	40° C. higher.	50° C. higher.
100	·24	·72	1·00	1·21	1·39	1·55
200	·94	1·67	2·10	2·55	2·90	3·20
300	2·10	2·92	3·58	4·11	4·58	5·02
400	3·75	4·73	4·45	6·18	6·80	7·36
500	5·86	6·72	7·54	8·23	8·88	9·49
600	8·44	9·41	10·27	11·11	11·85	12·57
700	11·49	12·51	13·28	14·16	14·92	15·64
800	15·00	15·95	16·86	17·70	18·51	19·30
900	18·98	19·94	20·84	21·27	22·58	23·40

Span. Feet.	Dip.					
	Lowest Probable Temperature.	10° C. higher.	20° C. higher.	30° C. higher.	40° C. higher.	50° C. higher.
1000	23·43	24·36	25·59	26·19	27·06	27·90
1100	28·36	29·33	30·27	31·20	32·09	32·96
1200	33·75	34 72	35·47	36·57	37·46	38·21
1300	39·61	40 59	41·43	42·52	43·45	44·36
1400	49·54	46·92	47·87	48·82	49·74	50·64
1500	52·73	53·82	54 70	55·69	56·65	57·58
1600	60·00	60·98	61·94	62·89	63·82	64·74
1700	67·73	68·68	69·63	70·53	71·04	71·99
1800	75·93	76·86	77·81	78·75	79·68	80·59
1900	84·60	85·56	86·51	87·45	88·39	89·31
2000	93·75	94·74	95·71	96·68	97·64	98·59

RED FIGURES APPROX SWG

FUSE TABLE (abridged). Preece.

The figures under end heading represent the diameter in mils of wires that will be fused by the currents in the first column. 1 mil = $\frac{1}{1000}$ = ·001 inch.

LEAD WIRE	Current. Amperes.		Copper.	Platinum.		Iron.	German Silver.		Tin.	Tin 1. Lead 2.
36 8·1	1	47	2·1	3·3	40	4·7	3·3	36	7·2	8·3
40	2	43	3·4	5·3	36	7·4	5·3	34	11·3	13·2
27	3	41	4·4	7·0	33	9·7	6·9	28	14·9	17·3
25	4	39	5·3	8·4	31	11·7	8·4	26	18·1	21·0
23	5	38	6·2	9·8	29	13·6	9·7	25	21·0	24 3
20	10	33	9·8	15 5	24	21·6	15·4	21	33·4	38·6
18	15	30	12·9	20·3	22	28·3	20 2	19	43·7	50·6
17	20	25	15·6	24·6	20	34·3	24 5	17	52·9	61·3
15	25	26	18·1	28·6	19	39·8	28·4	16	61·4	71·1
14	30	25	20·5	32 3	18·5	45·0	32·0	15	69·4	80·3
13·5 86·4	35	24	22·7	35·8	18	59·8	35·6	14·5	76·9	89·0

RED FIGURES APPROX SWG

FUSE TABLE (abridged)—*contd.*

Current. Amperes.	Copper.	Platinum.	Iron.	German Silver.	Tin.	Tin 1. Lead 2.
40	23 24·8	39·1	17 54·5	38·8	13·5 84·0	97·3
45	22 26·8	42·3	16·5 58·9	42·0	13 99·9	105
50	22 28·8	45·4	16 63·2	45·0	12·5 97·5	113
60	21 32·5	51·3	15 71·4	50·9	11 110	128
70	20 36	56·8	14 79·1	56·4	10 122	141
80	19 39·4	62·1	13·5 86·4	61·6	9·5 133	154
90	18·5 42·6	67·2	13 93·5	66·7	9 144	167
100	18 45·7	72·0	12 100·3	71·5	8·5 155	179
140	17 57·2	Platinoid about 6 per cent. more than German Silver.				
200	15 72·5					
250	15·5 84·1	Lead, 3 to 4 per cent. less than tin lead alloy.				
300	95					

These figures are only correct when a sufficient length of wire is taken. If the terminals are close together, all sizes will be reduced.

Wire-gauge Fusing Table.

Giving amperes needed to FUSE wires of various sizes (Preece).

S.W.G.	Diam. Mils.	Copper.	Platinum.	Iron.	German Silver.	Tin.	Tin 1. Lead 2.
14	80	232	117·0	71·2	118·0	37·2	29·8
16	64	166	83·7	51·0	84·7	26·6	21·3
18	48	108	54 4	33·1	55·6	17·3	13·9
20	36	70·0	35·3	21 5	35·7	11·2	9·00
22	28	48·0	24 2	14·8	24·5	7·69	6·18
24	22	33·4	16·9	10·3	17·1	5·36	4·30
26	18	24·7	12·5	7·5	12·6	3·97	3·18
28	14·8	18·4	9 31	5·67	9·42	2·96	2·37
30	12·4	14·2	7·14	4 35	7·22	2·27	1·82
32	10·8	11·5	5·81	3·53	5·87	1·84	1·48

Wires supposed so long that end effects may be neglected.

Apparatus A.—The insulation resistance is generally measured with a very sensitive portable galvanometer, and some portable Leclanché cells. The deflection is noted when the current is passing from—(*a*), one insulated lead to the other (all lamps, &c., being of course removed), and (*b*), when passing from either of the leads to earth (a water pipe). The resistances corresponding to the given deflections are known from a calibration curve, or calibration table.

The voltage used should be as high as possible. It should never be less than that of 10 Leclanchés.

A very high insulation resistance, which shows fluctuations from day to day, is more likely to develop into a fault than a lower resistance which shows no such fluctuations.

B.—The Goolden ohmmeter is a portable magneto apparatus, going up to 120 volts, and giving the resistance directly.

Mode of Testing.—If, when the mains are tested, the insulation resistance is found too low, the switches of the various circuits should be turned off one by one. If the deflection suddenly diminishes after turning off a particular switch, a fault in the circuit protected by this may be inferred. This

may not cut out a fault to earth, as switches are not usually double pole. It will, however, show the position of a leak from one wire to another.

If this test fails, there is a leak to earth on one of the wires not connected to a switch. The fuses must then be removed from the double pole cut-outs in the various circuits till the faulty wire is discovered. The wire in this circuit is then examined. If no fault can be detected here, the various fittings are disconnected, as these are a frequent source of leakage, especially on damp walls. When the fault has been discovered and repaired, the whole system should be tested once more.

Note.—When wires, and more especially fittings, are on damp plaster, the insulation is frequently low, but improves as the plaster dries.

Insulation resistance of dynamos and transformers should not be tested by Wheatstone's bridge, but by using electromotive forces at least twice as great as those to which they will be subjected when at work.

SUMMARY OF PHŒNIX FIRE OFFICE RULES.

(Extracted by permission of Musgrave Heaphy, C.E.)

For currents up to 100 ampères, a current density of 1000 ampères per square inch may be employed. For larger currents, a less current density must be used. In any case, the conductors must be absolutely safe with regard to heating, even if the current should become doubled.

No *naked* wires are allowed.

All conductors, fittings, &c., should be submitted, for approval, to the Fire Office before the installation is commenced.

All conductors must be in casing, unless permission is first obtained. when the two wires must be 6 inches apart for mains, and 2 inches for small branches; and they must be at least 2 inches from any conducting substance.

Special precautions must be taken where the risk is in any way unusual.

No earth return allowed under any conditions, either *via* ground, or gas or water pipes.

Conductors passing through external wall must be in separate earthenware or insulated metal tubes.

All joints must be soldered, and resin only may be used as flux.

There must be a fusible cut-out to every branch, to act when the current exceeds the normal by 50 per cent.

Mains and principal branches must be protected by double-pole cut-outs, and when accumulators are used, by double-pole switches also.

No cut-outs other than fusible ones may be used without special permission.

All cut-outs must be in accessible positions.

The primary conductors of transformers must be 8 to 12 inches apart, in separate waterproof and fireproof casings, and must be as short as possible. They must have double-pole switches and cut-outs, the latter to act with a current 25 per cent. above the normal. The transformer must be in a very secure, *dry* situation, and where it cannot be tampered with.

Where a connection between primary and secondary is possible, the secondary must be provided with an automatic apparatus to cut it out of circuit if the pressure rises above 400 volts.

All switch-boards, switches, cut-outs, &c.,

must have incombustible bases, and be so mounted that there is no fear of fire spreading from them.

Ceiling roses must be such that no strain is thrown on the pendent wires where attached to the terminals.

The protection of arc light circuits will depend on the particular conditions of the case.

All arc lights must have globes, enclosed at the bottom, and so that no sparks, &c., can escape, and the globes must be protected with wire netting.

Gas fittings should never be used for glow lamps, unless disconnected from earth, and preferably not even then.

Special permission must be obtained for multiple parallel or multiple series wiring.

No dynamo, motor, acccumulator, transformer, nor any generating apparatus may be placed in any working room (other than the engine, &c., rooms) of a woollen, flax, corn, or jute mill, or in any building considered a hazardous risk, unless permission is first obtained.

An electric power installation must be protected in the same way as an electric light installation if the conditions of electric supply and pressure are the same.

For pressures of 200 volts, or less, the insulation resistance of the installation must

not be below the following for each branch and for the whole circuit:—

25 lights	.. ..	500,000 ohms.
50 "	.. ..	250,000 "
100 "	.. ..	125,000 "
500 "	.. ..	25,000 "
1000 "	.. ..	12,500 "

And in proportion for other numbers of lights.

For alternating currents, double these numbers must be taken.

Pressure must never exceed 2500 volts on entering any house transformer. If generated at any higher pressure, and transformed down by an intermediate transformer, devices must be used to protect primaries of house transformers from ever rising to pressure higher than 20 per cent. above their normal.

Notice must be given to the Fire Office before the light is put on; and samples must be sent in of all conductors used, together with full particulars of the whole installation, fittings, and especially cut-outs.

TRANSMISSION AND DISTRIBUTION OF POWER.

I. TRANSMISSION WITHOUT DISTRIBUTION.—*One Motor only run from One Dynamo* (continuous current). — The motor and dynamo are preferably both *series-wound*, and if distance is short may be similar machines so that characteristics are alike. If the dynamo is run at constant speed, the motor also will run of itself at nearly constant speed, whatever its load. It will be more nearly self-regulating if motor is designed to give (at equal speed) about 10 per cent. lower volts than the dynamo. If distance is long, both machines should be wound to work at higher volts, and so that the volts of the motor (at same speed) should be lower than volts of dynamo by an amount equal to the resistance of the entire circuit multiplied into the maximum current transmitted.

If motor and dynamo are both *shunt-wound*, or both *compound wound*, they will also constitute a self regulating combination if the fall of potential in the line is equal to the difference between the volts at their terminals when each is separately run at equal speed. (N.B. When a compound

machine is used as dynamo, the shunt and series coils act *summationally;* when used as motor they act *differentially.*)

If motor and dynamo are unlike in winding, *regulating devices* must be used. For hand regulation a variable resistance should be employed. In series machines this resistance should be used as shunt to the field-magnet coils: in shunt machines it should be in series with them. Weakening the magnetic field *increases* the speed of the motor under a given load, if supply is at constant pressure, and *diminishes* it if supply is at constant current.

If *alternate current machines* are used as motor and dynamo, the motor will run at same speed as dynamo, provided that it is once started into sychronous running.

If multiphase alternate currents are employed, the motors will be self-starting; but three wires will be needed.

II. DISTRIBUTION OF POWER, to *more than one* motor, each being independent of the others.

(A) *Supply at Constant Pressure.*

(i) *Motors to run at Constant Speed.*—Motors are preferably compound wound (differential), or else shunt wound, and with very low armature resistance. At starting motor a resistance is inserted in armature circuit and switched out when speed is up,

but the field magnets are preferably switched at once right across mains. Alternate current motors usually synchronize.

It is useful to remember that in motors with fixed magnetism (as shunt motors on constant pressure supply) the speed depends only on the volts, and the torque depends only on the current.

(ii) *Motors to run at Variable Speeds, for Traction.*—Either shunt or series motors are employed. Speed varied by *inserting* resistance in the field magnet circuit of a *shunt* motor, or *shunting* the field magnets of series motor.

(B) *Supply with Constant Current.*—This method, which requires all motors to be in series, has been attempted for purpose of traction, and for motors to be used in arc-light circuits (see p. 10).

(iii) *Constant Speed.*—Unattainable yet, in series working, without special automatic regulators.

(iv) *Variable Speed.*

α. Torque constant at different speeds.—Constant current supply unsuitable.

β. Torque increases with load: as wanted for traction of cars and for saw mills. All motors in series and series wound. Regulate by shunting field magnets.

MAGNETIC UNITS.

Unit of Magnetism, or *Unit Pole*, is that which (supposed collected at a point) repels an equal similar unit with a force of one dyne at a distance of 1 cm. in air. From unit pole proceed 4π magnetic lines.

Magnetic Lines of Force are imaginary lines, drawn always along the direction of the resultant magnetic force in the field; and the number of them is chosen such that in a cross-section of the field there shall be *one line per sq. cm.* for *one dyne of force on unit pole.*

Strength of Field, or *Intensity of Magnetic Force at a point*, H (also called magnetic force at a point), is measured by the pull (in dynes) on unit pole supposed placed at that point. Hence the intensity of the magnetic force, H, may be conveniently expressed by saying that in a field where the intensity is H there would be H lines per sq. cm. if the field were occupied by air.

Unit Magnetic Field exerts a force of one dyne on unit pole, and is represented by one magnetic line per sq. cm.

Permeability, μ. Iron, steel and other magnetic materials are more permeable by magnetism than air is, and may be considered better conductors of magnetic lines. The same magnetising force which woul[d]

produce H lines per sq. cm. in air, will produce a much larger number, μ times H, in iron. The multiplier μ, which expresses the superior magnetic conducting power, is called the *permeability*. It varies in iron according to quality and degree of saturation, from 3000 down to 30 or less.

The Induction, or *the Permeation*, B is name given to actual number of magnetic lines per sq. cm. in the material, and is the same as μ times H. Hence $\mu = \mathsf{B} \div \mathsf{H}$. In air $\mathsf{B} = \mathsf{H}$, and $\mu = 1$. (See special table of values of B and μ, p. 65).

SURFACE DISTRIBUTION UNITS.

Strength of Pole, or *Quantity of Free Magnetism*, m, is number of units of magnetism as defined above. From pole of strength, m, proceed $4 \pi m$ magnetic lines.

Magnetic Moment, M, is product of strength of one pole into length between them $= m \times l$.

Intensity of Magnetisation, I, is magnetic moment per unit of volume. B and I are connected by the equation $\mathsf{B} = 4 \mu \mathsf{I} + \text{H}$.

Susceptibility, κ, is the ratio of I to H; it follows that $\mu = 4 \pi \kappa + 1$.

MAGNETIC CALCULATIONS.

Magnetism, which was formerly treated of as though it were something distributed over the end surfaces of magnets, is now

known to be a phenomenon of internal structure; and the appropriate mode of considering it is to treat magnetic materials, iron and the like, as being capable of acting as good conductors of the magnetic lines; in other words, as possessing magnetic *permeability*. Suppose a magnetic force—due, let us say, to the circulation of an electric current in a surrounding coil—were to act on a space occupied by air; there would result a certain number of magnetic lines in that space. The intensity of the magnetic force, symbolised by the letter H, is often expressed by saying that it would produce H magnetic lines per sq. cm. in air. Now, owing to the superior magnetic power of iron, if the space subjected to this magnetic force were filled with iron instead of air, there would be produced a larger number of magnetic lines per sq. cm. This larger number in the iron expresses the degree of magnetization in the iron; it is symbolised by the letter B. The ratio of B to H expresses the *permeability* of the material. The usual symbol for permeability is the Greek letter μ. B is equal to μ times H. The permeability of such non-magnetic materials as air, silk, cotton, and other insulators, also of brass, copper, and all the non-magnetic metals, is taken as $= 1$. In soft wrought iron the permeability is much higher than

in hard iron and in steel; but it varies also with the degree to which the magnetisation of the specimen has been pushed.

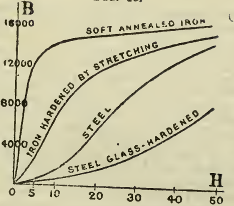
PROPERTIES OF IRON.

A convenient mode of studying the magnetic facts respecting any particular brand of iron is to plot on a diagram the curve of magnetisation—i. e., the curve in which the values, plotted horizontally, represent the magnetic force, H, and the values plotted vertically those that correspond to the respective magnetisation, B.

CURVES OF MAGNETIZATION (Ewing).

The curves relate to soft iron, hardened iron, soft steel and hard steel. In all these curves, for small values of H, the values of B are small; and as H is increased, B increases also. The curve rises suddenly, at least with all the softer sorts of iron, then bends over and becomes nearly horizontal. In the stage below the bend of the curve, the iron is said to be far from the state of saturation. When the magnetization has been pushed beyond the bend of the curve, the iron is said to be approaching saturation; because at this stage of magnetization it requires a large increase in the magnetizing force to produce even a small increase in the

FIG. 13.



magnetization. For soft wrought iron the stage of approaching saturation sets in when B has attained the value of about 16,000 lines per sq. cm., or when H has been raised to the value of about 50. In dynamo machines it is usual to push the saturation until B is from 16,000 to 20,000; or 7000 to 10,000 in cast iron. In transformers B rarely exceeds 7000.

The four curves given in Fig. 13, exhibit the relative values of μ and B for the same four specimens. Some numerical values are given on p. 65.

MAGNETIZATION OF IRON (from Hopkinson).

Annealed Wrought Iron.			Grey Cast Iron.		
B	μ	H	B	μ	H
5,000	3,000	1·6	4,000	800	5
9,000	2,250	4	5,000	500	10
10,000	2,000	5	6,000	279	21
11,000	1,692	6·5	7,000	133	42
12,000	1,412	8·5	8,000	100	80
13,000	1,083	12	9,000	71	127
14,000	823	17	10,000	53	188
15,000	526	28·5	11,000	37	292
16,000	320	50	—	—	—
17,000	161	105	—	—	—
18,000	90	200	—	—	—
19,000	54	350	—	—	—
20,000	30	666	—	—	—

Magnetic Circuit.

In calculating dynamos, transformers, and electromagnets, it is needful to consider the circuit (of iron, air, &c.) around which the magnetic lines flow.

Symbols used.

N, whole number of magnetic lines (C.G.S. definition of magnetic lines, see p. 60) that pass through the magnetic circuit. Also called the *magnetic flux*.

B, the number of magnetic lines per square centimetre, in the iron: also called the *induction*, or the internal magnetization.

H, the magnetic force or intensity of the magnetic field, in terms of the number of magnetic lines to the square centimetre that there would be in air.

R, the magnetic resistance, or reluctance, in the path of the magnetic lines.

μ, the *permeability* of the iron, &c.; that is its magnetic conductivity or multiplying power for magnetic lines.

A, area of cross section, in square centimetres.

l, length, in centimetres.

S, number of spirals or turns in the magnetizing coil.
i, electric current, expressed in amperes.
v, coefficient of allowance for leakage, being the ratio of the whole magnetic flux to that part of it which is usefully applied.

The whole magnetizing power of an electric current is proportional to the number of *amperes*, and to the number of *turns* or spirals in the coil in which it circulates. Let the whole *magneto-motive force* be called M.

$$\mathsf{M} = 1{\cdot}257 \times \mathrm{S} \times i.$$

H in a uniformly-wound coil equals $\mathsf{M} \div l$, provided the coil is long in proportion to its diameter.

MAGNETIC RESISTANCE, OR RELUCTANCE, of a magnetic conductor to the flow of magnetic lines through it, is proportional to its length, and inversely proportional to its sectional area and permeability. Hence,

$$\mathrm{R} = \frac{l}{\mathrm{A}\,\mu}$$

in a simple case, but it is more often the sum of a series of such terms.

Fig. 14 represents an electromagnet, having its circuit closed by an iron arma-

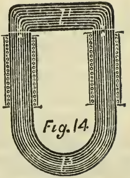


Fig. 14

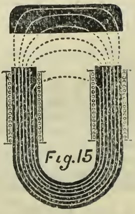


Fig. 15

ture. In this case the total magnetic reluctance of the circuit is

$$R = \frac{l_1}{A_1 \mu_1} + \frac{l_3}{A_3 \mu_3}.$$

In Fig. 15 the same electromagnet is shown with the armature at a distance. The intervening air-gaps offer additional reluctance. Also, magnetic leakage takes place, and to force N magnetic lines through the armature, there must be generated a larger number of magnetic lines $v\mathsf{N}$ in the magnet core; v being the coefficient of allowance for leakage, an improper fraction, increasing with the width of gap.

Law of Magnetic Circuit.

Resembles Ohm's law, used for electric circuits.

$$\text{Magnetic flux} = \frac{\text{Magneto-motive Force}}{\text{Magnetic Reluctance}};$$

or

$$\mathsf{N} = \frac{\mathsf{M}}{R}$$

whence

$$\mathsf{M} = \mathsf{N} \times R.$$

Using this law, it is possible to calcula e

the number of ampere turns of circulation of electric current needed to produce any prescribed number of magnetic lines as follows:—

Ampere-turns required to drive **N** lines through iron of armature

$$= \mathbf{N} \times \frac{l_1}{A_1 \mu_1} \div 1{\cdot}257.$$

Ampere-turns required to drive **N** lines through the two gaps

$$= \mathbf{N} \times \frac{2 l_2}{A_2} \div 1{\cdot}257.$$

Ampere-turns required to drive v **N** lines through the iron of magnet core

$$= v\mathbf{N} \times \frac{l_3}{A_3 \mu_3} \div 1{\cdot}257.$$

And, adding up:—

Total ampere turns

$$= 1{\cdot}257 \times \mathbf{N} \left\{ \frac{l_1}{A_1 \mu_1} + \frac{l_2}{A_2} + \frac{v\, 3}{A_3 \mu_3} \right\}.$$

Here l_2 is the length measured across the air-gap.

If dimensions are given in inches, the calculations become:—

Ampere-turns required to drive **N** lines through iron of armature

$$= \mathbf{N} \times \frac{l''_1}{A''_1 \, \mu_1} \times 0 \cdot 3132.$$

Ampere-turns required to drive **N** lines through two gaps

$$= \mathbf{N} \times \frac{2 \, l''_2}{A''_2} \times 0 \cdot 3132.$$

Ampere-turns required to drive v **N** lines through iron core of magnet

$$= v \, \mathbf{N} \times \frac{l''_3}{A''_3 \, u_3} \times 0 \cdot 3132.$$

And, adding up:—

Total ampere-turns required

$$= 0 \cdot 3132 \, \mathbf{N} \left\{ \frac{l''_1}{A''_1 \, \mu_1} + \frac{2 \, l''_2}{A''_2} + \frac{v \, l''_3}{A''_3 \, \mu_3} \right\}.$$

Pull of Electromagnets.

(I.) If P stands for pull of one pole, following formulæ hold good:—

$$P \text{ (in dynes)} = A \times B^2 \div 8\pi$$
$$P \text{ (in grammes)} = A \times B^2 \times 0 \cdot 0000405;$$
$$P \text{ (in pounds)} = A \times B^2 \times 0 \cdot 0000000893$$

or, if area A'' is given in sq. inches,

$$P \text{ (in pounds)} = A'' \times B^2 \times 0 \cdot 000000262.$$

(II.) To find the induction B necessary for a given pull:—

$$B = 5000 \times \sqrt{\frac{\text{P kilogrammes}}{\text{A sq. centims.}}}; \text{ or}$$

$$B = 1317 \times \sqrt{\frac{\text{P pounds}}{\text{A sq. inches}}}.$$

(III.) To find ampere-turns for a given induction B, if magnetic circuit is closed, and of uniform section and material

$$Si = 0 \cdot 8 \times l \times B \div \mu.$$

(IV.) These calculations are simplified by reference to Table on next page.

Magnetization and Pull of Electromagnets.

B lines per sq. cm.	Dynes per sq. centim.	Grammes per sq. centim.	Kilogrs. per sq. centim.	Pounds per sq. inch.
1,000	39,790	40·56	·0456	·577
2,000	159,200	162·3	·1623	2·308
3,000	358,100	365·1	·3651	5·190
4,000	636,600	648·9	·6489	9·228
5,000	994,700	1,014	1·014	14·39
6,000	1,432,000	1,460	1·460	20·75
7,000	1,950,000	1,987	1·987	28·26
8,000	2,547,000	2,596	2·596	36·95
9,000	3,223,000	3,286	3·286	46·72
10,000	3,979,000	4,056	4·056	57·68

MAGNETIZATION AND PULL OF ELECTROMAGNET—*continued.*

B lines per sq. cm.	Dynes per sq. centim.	Grammes per sq. centim.	Kilogrs. per sq. centim.	Pounds per sq. inch.
11,000	4,815.000	4,907	4·907	69·77
12,000	5,730,000	5,841	5·841	83·07
13,000	6,725,000	6,855	6·855	97·47
14,000	7,800,000	7,550	7·550	113·1
15,000	8,953,000	9,124	9·124	129·7
16,000	10,170,000	10,390	10·39	147·7
17,000	11,500,000	11,720	11·72	166·6
18,000	12,890,000	13,140	13·14	186·8
19,000	14,360,000	14,630	14·63	208·1
20,000	15,920,000	16,230	16·23	230·8

(V.) To find ampere-turns necessary to make an electromagnet exert a given pull (P = pull of 1 pole).

Case 1. When armature is in contact, and of same sectional area and material as core:—

$$\text{Ampere-turns} = 4000\,\frac{l}{\mu} \times \sqrt{\frac{\text{P kilograms.}}{\text{A sq. centms.}}};$$

or, if l'' and A'' are given in inch measures

$$\text{Ampere-turns} = 2050\,\frac{l''}{\mu} \times \sqrt{\frac{\text{P pounds.}}{\text{A}'' \text{ sq. ins.}}}.$$

Case 2. When the magnetic circuit is not of uniform section or material. First calculate the magnetic reluctance of the circuit, as on p. 67. Then

$$\text{Ampere-turns} = 4000 \times \sqrt{P \times A} \times R; \text{ or}$$

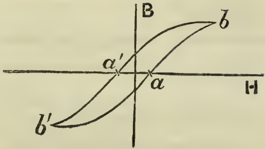
$$\text{Ampere-turns} = 4000 \times \sqrt{P \times A} \times \left\{\frac{l_1}{A_1\mu_1} + \frac{2l_2}{A_2\mu_2} + \frac{vl_3}{A_3\mu_3}\right\}.$$

N.B.—In above calculations the respective values of μ must be taken from the curve of magnetization (such as on p. 64), of the particular kind of iron in question; or from such tables as those on p. 65.

Energy Lost by Hysteresis.

If a piece of soft iron be magnetised to the point b, then demagnetised, magnetised in the opposite direction to the same extent, and once more brought to its original state, the whole cycle of operations will be represented by the following curves $b\,a_1\,b_1\,a\,b$ (Fig. 16). The descending curve $b\,a_1$ always lies to the left of the ascending curve $a\,b$. This is due to the lagging in phase of the magnetisation behind that of the magnetising force: an effect known as *hysteresis.*

Fig. 16.



The area enclosed represents energy wasted in the iron during the cycle. This energy is dissipated in heat. It is small with well annealed soft iron, and large in cast iron and steel. Whenever iron is magnetised and demagnetised in rapid succession (as in cores of transformers), the heat waste becomes an important quantity.

The following table (Kapp) shows the loss when the point b is carried up to various values of $\mathfrak{B}$.

HYSTERESIS. (Soft Annealed Iron.)

Maximum Induction per sq. cm.	Ergs Lost per Cycle per cub. cm.	Rate of Loss in Watts per cub. ft. with a frequency of 100 per sec.
3,000	1,200	340
4,000	1,600	450
5,000	2,300	650
6,000	3,000	850
7,000	3,700	1,050
8,000	4,500	1,280
9,000	5,500	1,560
10,000	7,000	2,000

Winding of Electromagnets.

First ascertain number of ampere-turns necessary to excite the required magnetism.

If the electromagnet is to be used in a circuit in which a current of a known number of amperes is to be supplied, the number of turns is at once calculable, and the tables on pp. 18 to 27 give the suitable gauge of wire.

Heating of Coils.—Approximate rule: Each square inch of surface, warmed to 1° (F.) above surrounding air, will emit heat at the rate of 0·001 watt; or, if 1 square inch of surface only be allowed per watt of heat wasted in the coil, the temperature will rise to 100° (F.) (Esson's rule). In practice the iron core also helps to dissipate heat.

If current density is 1000 amperes per sq. inch, rise in temperature (Fahr. deg.) = 69 × sectional area × number of turns per inch.

Resistance of coil of copper wire occupying v cubic inches of coil-space, and of which the gauge is d mils bare, and D mils covered is:—

$$\text{ohms} = 960700 \times \frac{v}{D^2 \times d^2}.$$

Approximate Rules.—If wrought-iron core

is to be magnetised up to $B = 16000$, so as to give pull of 150 lbs. per sq. inch, on armature, one inch length of coil, $\frac{1}{2}$ inch deep, will suffice (without undue heating) to magnetise 20 inches length of iron core. If armature is not in contact, but is so far away that half the magnetic lines leak away instead of going through armature, allow 8 inches length of coil, $\frac{1}{2}$ inch deep, for each inch of air-gap, in addition to amount allowed to magnetise iron.

Safe Limit of Temperature.—If this be taken at 90° (F.) above surrounding air, and electromagnet has resistance r and surface s (sq. inch), then:

$$\textit{Highest permissible amperes} = 0 \cdot 95 \sqrt{s \div r};$$

$$\text{or, } \textit{Highest permissible volts} = 0 \cdot 95 \sqrt{s \times r}.$$

To reach same limiting temperature, with bobbins of equal size wound with wires of different gauge, the cross-section of the wire must vary with the current it is to carry. (*See* Amperage Table, pp. 19 to 27.) In practice electromagnets that are only excited intermittently will not overheat if they are used with currents.

Similar electromagnets of different sizes must have ampere-turns proportional to their linear dimensions, if they are to be

raised to equal degree of magnetic saturation.

All magnet cores ought to be insulated from the windings. A coating of Aspinall's enamel, or Holmes's bath enamel, dried in a stove, is a good insulator.

The *leading-out* wires of electro-magnets are apt to give trouble by breaking off short, or by making short-circuits by contact with the cheeks. They should therefore be made of stronger wire, or still better of strip copper well-insulated with varnished tape.

Electromagnets intended to attract armatures which are at some distance from their poles will necessarily need to be so designed that they shall have a sufficient amount of ampere-turns to force the magnetic flux across the intervening gap: in other words, they must have long limbs to hold the requisite wire. Those electromagnets, on the other hand, that are merely required to hold tightly on in contact may be made quite short in limb, as few ampere-turns will force the magnetic flux through the closed circuit of iron.

WINDING BOBBINS.

Approximate Rules.

Let

Inner diam. of bobbin	$= a$	(inch).
Outer ,, ,,	$= b$	,,
Length between cheeks	$= c$	,,
Diam. of covered wire	$= D$	,,
,, bare ,,	$= d$	,,
Resistance of coil	$= R$	(ohms).

For copper—

$$R = 0 \cdot 00000085 \times (b^2 - a^2) \times c \div (D^2 \times d^2).$$

For German silver—

$$R = 0 \cdot 00001089 \times (b^2 - a^2) \times c \div (D^2 \times d^2).$$

If winding is good and close, approximate weight of wire is

$$W t \text{ (pounds)} = 0 \cdot 25 \times (b^2 - a^2) \times c \times d^2 \div D^2.$$

PERMANENT MAGNETS.

LIFTING POWER OF MAGNETS.—The rule is:—

Load $= a \times$ *the square of the cube root of magnet's own weight.* Here a is a coefficient depending on the goodness of the magnet, its form, and on the unit of weight chosen. For horseshoe magnets of best quality $a = 25$ if weights are given in lb.; or $a = 20$ if weights are given in kilogrammes. For bar magnets $a = 6\frac{1}{2}$, if weights are in lb., or 5 if weights are in kilogrammes.

Short bar magnets should be made glass hard before magnetizing. Bar magnets that are as much as forty diameters in length, and all horseshoe magnets, should be tempered down to a straw tint. Magnets for use in magnetic measurements are required to be extremely constant in their properties, and should be prepared as follows:—Make glass-hard; then boil in water for at least six or seven hours; when cold magnetize upon an electro-magnet; then boil for another hour; then remagnetize.

Never slam on the keeper of a horseshoe magnet; slide it on. You may detach it as suddenly as you like, but you must not slam it on, or you will weaken the magnet.

ELECTROMAGNETIC UNITS.

AMPERE; $= 10^{-1}$ C.G.S. unit of current. Current which deposits 0·001118 gramme of silver per sec.; or 4·0248 grammes per hour; almost exactly 1 *grain of silver per minute.*

VOLT; $= 10^8$ C.G.S. units of electromotive-force. Is 0·6974 of the electromotive-force of standard Clark's cell at 15° C.

OHM; $= 10^9$ C.G.S. units of resistance. *True* ohm, now adopted by international agreement, is resistance of uniform column of mercury 106·3 cm. long (and 1 sq. millim. in cross section), weighing 14·4521 grammes, at 0° C. [Roughly represented by the resistance of 100 yards of ordinary iron telegraph wire.] So-called "legal" ohm was taken as resistance of column of mercury 106 cm. long and 1 sq. millim. section, and was nearly $\frac{1}{3}$ of 1 per cent. less than true value. Old "B.A. unit" was resistance of a certain wire kept at Cambridge, and was about $1\frac{1}{2}$ per cent. less than true ohm. "Siemens' unit" was column of mercury 100 cm. long and 1 sq. millim. section at 0°, and was about 6 per cent. less than true ohm.

	True Ohm.	"Legal" Ohm.	"B.A." Unit.	Siemens' Unit.
True ohm	1·0000	1·0025	1·0138	1·0630
"Legal" ohm ..	0·9975	1·0000	1·0113	1·0600
"B.A." unit ..	0·9863	0·9889	1·0000	1·0482
Siemens' unit ..	0·9408	0·9434	0·9540	1·0000

Megohm; (practical unit for expressing insulation resistance) = 1,000,000 ohms.

Microhm; (frequent unit for specific resistances) = 1 millionth of 1 ohm.

Coulomb; $= 10^{-1}$ C.G.S. unit of quantity of electricity. Equals 1 ampere-sec. Deposits 0·001118 gramme silver.

WATT (or volt-ampere); $= 10^7$ C.G.S. units of power. Calculated by multiplying together volts and amperes. 1 watt $= \frac{1}{746}$ of a horse-power. 1000 watts is called 1 *kilowatt.*

KILOWATT-HOUR (or *Board of Trade Unit* of Electric Energy), is quantity of energy supplied in one hour by a current at such a pressure that product of volts, amperes, and hours comes to 1000. Example: current of 10 amperes at 100 volts for 1 hour; or current of 4 amperes at 20 volts; or $12\frac{1}{2}$ hours.

MICROFARAD (Practical Unit of Capacity) $= 10^{-15}$ C.G.S. unit of capacity. Is capacity of a condenser which takes only 1 milionth of 1 coulomb to charge up to 1 volt. (Condenser of paraffined paper and tinfoil to have capacity 1 mfd. will have about 37 sheets of foil $7\frac{1}{4}$ by 6 inches each.) Static capacity of 1 nautical mile of Atlantic cable $=$ about $\frac{1}{3}$ mfd.

HENRY (or quadrant); (practical uuit of self-induction) $= 10^9$ C.G.S. units of self-induction, is such that turning on unit current causes a virtual cutting of 10^9 lines.

E.M.F. of Clark Standard Cell at Different Temperatures.

E.M.F. of Clark cell $= 1{\cdot}434$ at $15°$ C. $= 1{\cdot}434\ (1 - {\cdot}00077\ [t - 15])$ at a temperature $t°$ C.

Temp.	E.M.F.	Temp.	E.M.F.
5°	1·441	16°	1·433
6	1·441	17	1·432
7	1·440	18	1·432
8	1·439	19	1·431
9	1·439	20	1·430
10	1·438	21	1·429
11	1·437	22	1·429
12	1·436	23	1·428
13	1·436	24	1·427
14	1·435	25	1·426
15	1·434	26	1·425

P. O. Standard Daniell Cell. — Saturated zinc sulphate and saturated copper sulphate. E.M.F., 1·055 true volts.

Leclanche Cell (new) .. 1·45 volts.
Grove Cell .. .. .. 1·93 volts.
Accumulators .. 2·0 to 1·9 volts.

Units of Current.

	C.G.S.	Ampere.	Daniell / Siemens.	Silver, grms. per hour.	Copper, grains per hour.
C.G.S. (electro magnetic ..	1	10	8·5	40·25	0·76
Ampere	0·1	1	0·85	4·025	0·076
Daniell ÷ Siemens unit	0·117	1·17	1	4·709	0·0889
Silver, grms. per hour ..	40·25	4·025	4·709	1	52·9
Copper, grns. per hour ..	0·76	0·076	0·0889	0·0189	1

N.B.—One ampere in one second liberates 0·00010352 gramme of hydrogen, or 0·001118 gramme of silver.

ARC LAMPS.

Keep all parts clean. See that proper contact is made with the carbon holders, no sparking to guides. Clean working parts with rag moistened with paraffin oil. *Never use emery cloth.* Lubrication, if required at all, by good clock oil.

Causes of failure of Lamps.

(1.) Dirty working parts, hardened oil &c. Clean with paraffin. See that no screws have worked loose.

(2.) Working parts worn. This occurs at guides, indiarubber or other gripping parts of clutch, if any, &c.

(3.) Bent carbon holders, allowing carbons to slide past each other.

(4.) Carbon holders in clutch lamps being roughened or pitted by wear of clutch, or by sparking through imperfect electrical connection. *At once renew.*

(5.) Loose connections or coils being burnt out. Coils fail to attract.

(6.) Pumping. Generally caused by too small a current. Lamps often pump if run on a constant potential circuit of low voltage (50 to 60, or 2 on 100 volts). In this case put in an inductive resistance (see page 6), or put a dashpot on lamp with glycerine and water or oil.

HINTS ABOUT DYNAMOS.

Before starting up, see that brushes, properly trimmed, are raised above the commutator, lubricators filled, belt tight. After starting, put down the brushes. At end of run, switch off current, raise the brushes, then slow down.

If dynamo sparks at brushes shift the rocker until sparkless position is found. If this does not cure sparking, examine brushes to see whether properly trimmed, and whether they bear with sufficient pressure on commutator. If need be, tighten springs in brush-holder or remove brushes and trim with file. Commutator should not be oiled, but touched lightly with linen rag and vaseline.

If dynamo refuses to excite itself, examine brushes to see if contact good, pressure sufficient, and commutator clean. If still unsuccessful, examine circuit to see if any safety fuse has burned out or switch been left open. Remember shunt-wound dynamos excite best on open circuit; and series-wound dynamos on short circuit. If still no result, stop running and test for a possible disconnection. In absence of other testing appliances, put on a Leclanché cell or two, and try whether you can ring an electric bell through the

dynamo. Test similarly for a possible disconnection in the shunt, after raising the brushes off the commutator. Try changing field-magnet connections so that current shall circulate the other way.

If commutator has cut into ruts all round, you are putting too much pressure on brushes. If it has worn into "flats" at any of the bars either the brushes jump mechanically, causing spark, or there is a faulty connection in the armature. Turn down the commutator till it is true, and tighten the springs in the brush-holder.

ELECTRIC POWER.

To ascertain the Horse-power of a Motor. —Multiply together the number of amperes of current that the armature will carry, and the number of volts of pressure at the mains for which the motor is designed (these are usually marked on the motor); then divide the product by 746. This will give the electric horse-power absorbed by the motor from the mains. A good motor will give out as mechanical power more than 80 per cent. of the electric power thus supplied to it.

Speed of Motors.—When a motor is supplied at constant pressure from the

mains, its speed will be slower the stronger the magnetism of its field-magnet.

Torque of Motors.—The torque or 'effort,' or 'turning moment' of a motor is simply proportional on the current in its armature, to the magnetism of the field-magnet, and to the number of windings on the armature. It does not depend on the speed except in so far as the speed causes the current in the armature to vary. All motors when they run generate counter electromotive forces, which tend to cut down the current. A motor running without any load tends to increase its speed to such a point that its own electromotive force is equal to the volts of pressure at the mains, when the current is reduced to a minimum.

In Motors supplied at constant pressure, and with magnet excited independently or by shunt, the *torque* is greatest when current is greatest, when speed is zero at starting: the *speed* is greatest when torque and current are least, when running without load: the *horse-power* is greatest when current is half that at starting, and speed half that on no load, and in this case efficiency is only 50 per cent.: the *efficiency* is greatest when speed or magnetism is greatest, that is to

say when the counter volts generated in the armature are a large fraction of the applied volts, and when therefore the current is cut down to a small fraction of its initial value.

Transmission of Power.—Suppose a line is given for the transmission. The product of the resistance of the line into the current that is proposed to be sent into it will give the drop in pressure between the dynamo and the motor. For example: let a line 10 miles long consist of a stranded copper wire of 7 No. 16 S.W.G. The total resistance will be 19·5 ohms. Suppose a current of 20 amperes sent through this, the drop will be 390 volts. Suppose the dynamo to generate 1500 volts at its terminals, then the motor should be designed to generate 1110 volts when running at its proper speed. The power generated at the sending end will be $1500 \times 20 = 30{,}000$ watts ($= 40 \cdot 2$ H.P.) and that utilised at the receiving end will be $1110 \times 20 = 22{,}200$ watts ($= 29 \cdot 7$ H.P.); the difference being due to drop of pressure in the line. If two identical machines are used as dynamo and motor, the efficiency of the combination is practically equal to the ratio of their respective speeds.

Setting up Cells.—The acid must be of spec. grav. 1190, and be free from arsenic. The whole of the acid should be mixed in readiness, and allowed to cool. After the cells are all connected up, the polarity of the dynamo ascertained (see Pole Testers), and everything ready for charging by turning on a switch, the cells should be filled with acid *as quickly as possible*, and charging *at once* commenced. This initial charging should go on as continuously as possible for at least 24 hours, and as much longer as possible.

Note.—In mixing acid, always add the strong acid to the water, never *vice versa*.

Charging.—For economical working the charging current must not be outside the limits specified.

Sulphated Cells should be charged with a *small* current density for a long time till restored. See that the spaces between the plates are clear.

Proper specific gravity of Acid.—This should be 1200 when charged.

Discharging.—The discharge currents should not be in excess of those specified.

or the plates are liable to buckle and lose their paste.

Voltage must not fall below 1·85 *per cell.*

General.—Examine the cells frequently for displaced pellets, scaling or buckling. In case of the latter fault, remove the section and press flat between boards.

With old type cells it is sometimes advisable to remove one or two plates, and to put the remaining ones farther apart, with separators.

Always keep plates well covered with acid.

Keep acid up to 1200 when charged. For this purpose add acid of 1300 gravity when necessary; *never the undiluted acid.*

Where cells are used for irregular work without regular charging, the plates will keep in better condition if about $\frac{1}{2}$ oz. of sulphate of soda is added to each gallon of electrolyte.

Pole Testing.—It is an excellent precaution to test the polarity of the dynamo each day before charging. This can readily be done by momentarily joining the cells to the dynamo, through an incandescent lamp. If the lamp glows, the dynamo has become reversed.

Another pole tester is made by dipping two lead strips joined to the terminals of the machine into very dilute sulphuric

acid. The terminal joined to the plate which goes brown is the positive terminal, and should be joined to the positive or brown plates of the cells.

Dynamos.—Shunt machines only should be used. If the machine is compound-wound, the series winding must be cut out.

Reversing polarity of Dynamo.—This is most readily done by lifting the brushes from the commutator, and then switching the cells on to the dynamo. The magnets are in this way excited in such a direction as to make the machine charge the cells properly. It is an excellent plan to take this precaution every time the cells are charged.

E. P. S. Cells.

For Ordinary Work, where large capacity and not a very high rate of discharge are required, the **L** type is to be used. It is manufactured in the sizes as shown in Table on p. 97.

For High Discharges. — The **K** type. Compared with the **L** type it is more expensive for a given capacity, but less so for a given rate of discharge.

In *glass* boxes it is made in the same sizes as the **L** type.

In *wood* boxes it is made with 9, 13, 17,

21, 25, 29, and 33 plates, and corresponding charge and discharge rate.

Discharge Rate.—Double that of same sized **L** cell, i. e. 8 amperes per *positive* plate.

Capacity.—28 to 36 ampere-hours per + plate at maximum rate of discharge, or 32 to 42 (i. e. same as **L**) if at half the discharge rate.

Portable Cells.—**C** type, made to go under seats of railway carriages.

No. of Plates.	Discharge, Amperes.	Capacity, Ampere-Hours.	Length of Cell.
9	1 to 8	72	6 in.
15	1 „ 14	136	$9\frac{1}{2}$ „

Width, 14 in.; height over all, $8\frac{1}{4}$ in.

V type.—Several cells in series in one case for lighting single lamps. Made with 4 or 8 cells, and with discharge rates of 3 or 4 amperes.

L Type Cells.

No. of Plates.	Charge, Amperes.	Discharge, Amperes.	Capacity, Ampere-Hours.	Length of Cell.	
				Wood.	Glass.
7	10 to 13	1 to 13	130	$5\frac{1}{4}$	$5\frac{1}{2}$
11	16 ,, 22	1 ,, 22	220	$7\frac{1}{2}$	8
15	25 ,, 30	1 ,, 30	330	$9\frac{1}{2}$	$9\frac{5}{8}$
19	30 ,, 35	1 ,, 35	420	12	$12\frac{1}{4}$
23	38 ,, 46	1 ,, 46	500	$14\frac{3}{4}$	$14\frac{1}{2}$
27	45 ,, 50	1 ,, 50	580	$16\frac{7}{8}$	$17\frac{1}{4}$
31	50 ,, 60	1 ,, 60	660	$19\frac{1}{4}$	$18\frac{1}{2}$

Height over all $20\frac{1}{2}$ in. *wood*, and 16 in. *glass*.
Width, $13\frac{1}{4}$ to $13\frac{3}{4}$ in. *wood*, and $11\frac{1}{2}$ to 12 in. *glass*.
Per positive plate, discharge = 4 amperes; charge, 3 to 4; capacity, 45 ampere-hours.

T TYPE CELLS (Tramcars, Launches, &c.).

No. of Plates.	Discharge.	Capacity.	Length.	Width.	Height over all.
11	20	66	7	9	$13\frac{1}{2}$
15	30	95	9	,,	,,
19	40	120	11	,,	,,
23	50	145	$13\frac{1}{4}$	,,	,,

Supplied in wood boxes. Also in ebonite, about 1 in. less in all dimensions.

B TYPE CELLS (with sloping sides, for launches).

11	30	90	$6\frac{7}{8}$	11	13
15	40	120	9	,,	,,
19	50	150	$11\frac{1}{8}$	,,	,,

Crompton-Howell Cells.

These cells are specially suited for central station work, ammeter calibration, &c., where a very heavy rate of discharge for a short time is occasionally wanted.

No. of Plates.	Ordinary rate of Discharge.	Capacity, Ampere-hours.	Maximum rate of Discharge for 1 hour.	Size of all.
11	18	220	85	8 × 12 × 12
17	28	340	135	13 × 12 × 12
21	35	420	170	16 × 12 × 12
31	51	620	250	$28\frac{1}{2}$ × 12 × 12
61	100	1200	500	54 × 12 × 12

Normal Discharge.—$3\frac{1}{2}$ amperes and 43 ampere-hours per *positive* plate. *Maximum rate of Discharge.*—17 amperes per *positive* plate with much diminished capacity.

EPSTEIN CELLS.

No. of Plates.	Charge or Discharge, Amperes.	Capacity, Ampere-hours.	Dimensions. (All 17 in. high.)
3	1 to 30	120 to 150	$3\frac{1}{3} \times 15$
5	1 ,, 60	240 ,, 300	$5\frac{1}{2} \times 15$
7	1 ,, 90	360 ,, 450	$7\frac{1}{2} \times 15$
9	1 ,, 120	480 ,, 600	$9\frac{1}{2} \times 15$
11	1 ,, 150	600 ,, 750	$11\frac{1}{2} \times 15$

Normal Discharge.—30 amperes and 120 to 150 ampere-hours per *positive* plate. The discharge rate may be doubled for short periods. If halved, the capacity rises to 140 to 170 ampere-hours.

Numerical Statistics on Electro-metallurgy.

Copper.

Current	1	ampere	deposits	0·000326 gramme	per	second.
,,	1	,,	,,	0·01957 ,,	,,	minute.
,,	1	,,	,,	1·1739 ,,	,,	hour.
,,	851·8	,,	,,	1 kilogramme	,,	,,
,,	386·4	,,	,,	1 pound	,,	,,

To deposit 100 lb. of copper in a working day of ten hours will require 3864 amperes of current flowing all the time; or, if conducted in ten baths in series with one another will require 386·4 amperes, but in that case the dynamo will require to be of an electromotive-force ten times as great as for one single large bath. If electrolysis of the crude copper solution is carried on with carbon anodes, there will be required about 1·2 volts for each bath in series, or, at most, 15 volts for the ten baths.

Silver.

Current of	1	ampere deposits	4·025	grammes	per hour.
,, ,,	248·5	,, ,,	1	kilogramme	,,
,, ,,	112·7	,, ,,	1	pound	,,

Gold.

Current of	1	ampere deposits	2·441	grammes	per hour.
,, ,,	409·7	,, ,,	1	kilogramme	,,
,, ,,	185·8	,, ,,	1	pound	,,

Nickel.

Current of	1	ampere deposits	1·099	grammes	per hour.
,, ,,	910·1	,, ,,	1	kilogramme	,,
,, ,,	412·8	,, ,,	1	pound	,,

Pressure at Terminals required in Electro-deposition for Different Kinds of Baths.

	Volts.
Copper (acid bath)	0·5 to 1·5
,, (cyanide bath) ..	3 ,, 5
Silver	0·5 ,, 1
Gold	0·5 ,, 4
Brass	3 ,, 4
Iron (steel-facing)	1 ,, 1·3
Nickel on iron, steel, copper, with nickel anode, strike deposit with 5 volts, diminishing to ..	1·5 ,, 2
Nickel on iron, steel, copper, with carbon anode	2 ,, 4
Nickel on zinc	4 ,, 7
Platinum	5 ,, 6
Cobalt	1·5 ,, 4

Acid baths should not be used for depositing any metal upon zinc, iron, pewter, or britannia metal: for these cyanide (alkaline) baths should be used. In plating such soft metals with nickel it is preferable to give them a thin intermediate coating in a copper (cyanide) bath.

Current Density for Proper Deposit.

	Amperes per 100 sq. in.
Copper Typing—	
Best quality tough deposit	1·5 to 4
Good and tough (for clichés)..	4 „ 10
Good solid deposit .. .	10 „ 25
Solid deposit, sandy at edges	25 „ 40
Sandy and granular de-deposit	50 „ 100
Copper (cyanide bath) ..	2 „ 3
Zinc (for refining)	2 „ 3
Silver	1 „ 3
Gold	0·5 „ 1
Brass	3 „ 3·5
Iron (steel-facing)	0·5 „ 1·5
Nickel at first deposit 9 to 10 amperes per 100 sq. in., diminishing afterwards to	1 „ 2

If a half saturated solution of *nitrate of copper* is used and kept in *brisk agitation*, copper types may be deposited in one-tenth the usual time required for deposition.

ALTERNATE CURRENTS.

Alternating currents are those in which the electricity, instead of flowing steadily in one direction around the circuit, is kept oscillating forward and backward at a very high frequency, the electromotive-force being impressed in a series of waves, as it were, by the action of the alternate-current dynamo (or *alternator*). The usual *frequency* (or *periodicity*) of alternations used in England is 100 complete periods per second. (Ferranti uses 86, Westinghouse 133). As result of this very rapid ebb and flow of current in the circuit it is found that the waves of current lag behind the waves of impressed electromotive-force: this lag being due to the *self-induction* (or electromagnetic inertia) of the circuit. Any coil or electromagnet in the circuit acts as an *inductive resistance*, producing both a lag in phase and a diminution of the effective electromotive force. If *frequency* (number of periods per second) be denoted by n, and *coefficient of self-induction* (henries) by L, then the *inductance* is calculated as $2 \pi n \mathrm{L}$; being proportional to both these. The lag in phase depends on both inductance and

resistance, being such that $\tan \phi = 2 \pi n L \div R$; where is the angle of lag. If the impressed electromotive-force follows a sine-function, the effective electromotive-force can be calculated by multiplying by $\cos \phi$. To make Ohm's law applicable to alternate currents we must apply this correcting factor and then write:—

$$\text{alternating current} = \frac{\text{alternating impressed E.M.F.} \times \cos \phi}{\text{resistance}}.$$

Alternate-current amperemeters (electro-dynamometers, etc.) tell the *virtual* amperes; and alternate-current voltmeters (hot-wire, such as Cardew's, or electrostatic, such as Lord Kelvin's) tell the *virtual* volts. Virtual, in this sense, means the square-root of the mean square of the values, not the mere arithmetical mean. Hence the above equation signifies that the virtual amperes are always, in a circuit of given resistance, *less* than one would expect by calculating from the virtual volts, the diminution being greater as the lag is greater.

The *impedance* to the flow may be written as $= \sqrt{R^2 + 4 \pi^2 n^2 L^2}$. If the waves of electromotive-force do not follow sine-functions the impedance will be greater than this. Moreover, especially with very

rapid frequencies, the currents move mainly in the outer parts of the copper conductors, the inner parts being practically idle below a certain depth. When this is the case, the actual resistance of the conductor is greater than its resistance as measured by a Wheatstone bridge. Hence mains for alternate currents are often made hollow.

The following table gives result of calculations originated by Lord Kelvin:—

Diameter (millimetres).		10	15	20	25	40
		Percentage Increase of Resistance.				
Frequency:— Periods per second	80	0·7	2·5	8	17·5	68
	100	1	4	11·5	—	—
	133	1·5	7·2	18·5	—	—

Increase of resistance may be approximately calculated as follows: for conductor, diameter d (inches) at frequency n (periods per second).

$$\text{Increase of R} = d^4 n^2 \div 83{,}300.$$

Alternate Current Power.

Owing to lag, true mean power supplied in alternate current circuit is less than apparent mean power as calculated by multiplying together the virtual amperes and virtual volts. If a "non-inductive wattmeter" is not used, resort must be had either to the 3-dynamometer method of Blakesley, or to the 3-voltmeter method of Ayrton, or some analogous method.

In order that a wattmeter (electrodynamometer) may be reliable for measuring alternate-current power it is needful that the fine-wire circuit, which is to be connected as a shunt to the apparatus under measurement, should have as little self-induction as possible in proportion to its resistance. The latter may be increased by adding auxiliary non-inductive resistances. The instrument must itself be so constructed that there shall not be any eddy currents set up by either circuit in the frames, supports, or case; otherwise the indications will be false. In a three-phase (Drehstrom) system, the power can be measured by using two electrodynamometers so arranged that the current through the thick-wire circuit of the one instrument, and the voltage on the thin-wire circuit of the other instrument, shall belong to one branch of the system, and vice-versa for a second branch. The mean power is then the difference between the readings.

Lightning Rods.

Professor Lodge's researches have led him to certain practical conclusions, of which the following is a summary:

(a) All parts of a lightning conductor should be made of one and the same metal, avoiding joints as far as possible, and with as few sharp bends or corners as possible.

(b) The use of copper for lightning rods is a needless extravagance. Iron is by far the best metal. Ribbon has a slight advantage over round rod; but ordinary galvanized iron telegraph wire is good enough.

(c) The conductor should terminate not merely at the highest point of a building, but be carried to all high points. It is, however, not wise to erect very tall pointed rods projecting several feet above the roof.

(d) A good deep, wet "earth" should be provided independent of gas or water mains.

(e) If in any part the conductor goes near a gas or water-pipe it is better to

connect them metallically than to leave them apart.

(*f*) In ordinary buildings the conductor should be insulated away from the walls, so as to lessen the liability of lateral discharge to metal stoves and things inside the house.

(*g*) Connect all external metal work—zinc spouts, iron crest ornaments and the like—to each other, and to earth, but *not* to the lightning conductor.

(*h*) The cheapest way of protecting an ordinary house is to run common galvanized iron telegraph wire up all the corners, along all the ridges and eaves, and over all the chimneys; taking them down to the earth in several places, and at each place burying a load of coke.

(*i*) Over the top of tall chimneys it is well to take a loop or arch of the lightning conductor, made of any stout and durable metal.

The shaft of the Manchester Square station of the Metropolitan Electric Supply Company is protected by 4 galvanized iron wires, one up each corner, joined at intervals by horizontal bands of similar wire.

Units of Length.

1 metre = 39·3708 inch : 1 inch = 0·0254 metre.
1 centim. = 0·3937 inch : 1 inch = 2·54 centimetre.
Approximate rule, $30\frac{1}{2}$ centims. = 1 foot.

1 kilometre = 3281 feet : 1 mile = 1615·4 metres.
1 kilometre = 0·6215 mile : 1 mile = 1·6154 kilometres.
Approximate rule, 1 kilometre = $\frac{5}{8}$ mile.

1 millimetre = 0·1 centimetre = 0·03937 inch = $39\frac{1}{3}$ mils.
1 mil. = 1/1000 inch = 0·0025 centim. = 0·0254 millim.
Approximate rule, 1 millimetre = 40 mils.

1 knot (cable) = 1 nautical mile = 2029 yards = 1·856 kiloms.
1 knot (sailing) = 1 nautical mile per hr. = 101·4 ft. per min.

Units of Area, Volume, Mass.

Area.

1 sq. centim. = 0·155 sq. inch: 1 sq. inch = 6 451 sq. centim.
1 sq. metre = 1·196 sq. yard = 10·764 sq. feet = 1550 sq. inch.
1 sq. yard = 9 sq. feet = 0·8361 sq. metre = 8360 sq. centim.
1 hectare = 10000 sq. metre = 11960 sq. yards = 2·71 acre.
1 acre = 4840 sq. yards = 4046 7 sq. metres = 0·405 hectare.

Volume.

1 cub. centim. = 0·0610 cub. in. : 1 cub. in. = 16 386 cub. centim.
1 litre = 1000 cub. centim. = 61 03 cub. inch = 0·2201 gallon.
1 gallon = 4·543 litres = 277·274 cub. inch = 4543 cub. centim.

Mass

1 gramme = mass of 1 cub. centim. distilled water at 4° C.
= 15·432 grains = 0·002205 pound.
1 kilogramme = mass of 1 litre distilled water at 4° C.
= 1000 grammes = 2·205 pounds.
1 tonne = mass of 1 cub. metre distilled water at 4° C.
= 1000 kilos. = 2205 pounds.
1 pound = 16 oz. = 7000 grains = 453·6 grammes = 0·4536 kilo.
1 ton = 2240 pounds = 1016 kilos. = 1·016 tonne.

N.B.—In Germany the *pfund* = ½ kilogramme.

UNITS OF FORCE, PRESSURE, WORK, POWER.

Force.

1 *dyne* = that force which acting on 1 gramme for 1 second gives it a velocity of 1 centimetre per second (being absolute unit of force in the C.G.S. system, independent of local variations of gravity).

1 *gramme weight* = at Paris, 980 dynes; at London, 981 dynes; at Glasgow, 982 dynes.

1 *pound weight* = 453·6 grammes' weight = at Paris, 444,528 dynes; at London 444,987 dynes.

Pressure.

1 *pound per square inch* = 0·0703 kilogramme per square centimetre.

1 *kilogramme per square centimetre* = 14·2 pounds per square inch.

1 *atmosphere* = 30 inches of mercury = nearly 76 centimetres of mercury = nearly 15 pounds per square inch = nearly 1,000,000 dynes per square centimetre.

C × EX · 224 =

Work or Energy.

1 *erg* = work done by force of 1 dyne through distance of 1 cm. (being absolute unit of work in C.G.S. system); = 0·001019 gramme-cm.; = 0·00000007386 foot-pound (at London).

1 *gramme-cm.*, at London = 981 ergs = 0·0000724 foot-pounds.

1 *kilogramme-metre*, at Paris = 98,000,000 ergs = 7·234 (London) foot-pounds.

1 *foot-pound*, at London = 13,540,000 ergs = 0·138 kilogramme-metre.

1 *foot-pound*, at Glasgow = 13,550,000 ergs.

1 *Board of Trade unit* = 1000 watt-hours = 2,654,000 (London) foot-pounds.

Power.

1 *watt* = 10,000,000 ergs per sec. = 0·738 (London) foot-pounds per second = $\frac{1}{746}$ H.P.

1 *Horse-power* = 550 foot-pounds per sec. = 33,000 foot-pounds per min. = (at London) 746 watts = 1·014 Cheval-vapeur = 76·05 kilogramme-metres per second.

Cheval-vapeur (or metric H.P.) = 75 kilogr.-metres per sec. = 542·5 foot-pounds per sec. = (at Paris) 735 watts = 0·987 H.P.

1 *kilowatt* = 1000 watts = 10^{10} ergs per sec. = (at London) 1·34 H.P. = (at London) 44,236 foot-pounds per minute.

LOGARITHMS OF NUMBERS FROM 0 TO 23.

No.	0	1	2	3	4	5	6	7	8	9	Prop.
0	0	00000	30103	47712	60206	69897	77815	44510	90309	95424	
10	00000	00432	00860	01284	01703	02119	02531	02938	03342	03743	415
11	04139	04532	04922	05308	05690	06070	06446	06819	07188	07555	379
12	07918	08279	08636	08991	09342	09691	10037	10380	10721	11059	344
13	11394	11727	12057	12385	12710	13033	13354	13672	13988	14301	323
14	14613	14922	15229	15534	15836	16137	16435	16732	17026	17319	298
15	17609	17898	18184	18469	18752	19083	19312	19590	19866	20140	281
16	20412	20683	20952	21219	21484	21748	22011	22272	22531	22789	264
17	23045	23300	23553	23805	24055	24304	24551	24797	25042	25285	249
18	25527	25768	26007	26245	26482	26717	26951	27184	27416	27646	234
19	27875	28103	28330	28556	28780	29003	29226	29447	29667	29885	222
20	30103	30320	30535	30750	30963	31175	31387	31597	31806	32015	212
21	32222	32428	32634	32838	33041	33244	33445	33646	33846	34044	202
22	34242	34439	34635	34830	35025	35218	35411	35603	35793	35984	193
23	36173	36361	36549	36736	36922	37107	37291	37475	37658	37840	185

LOGARITHMS OF NUMBERS FROM 24 TO 38—*continued*.

No.	0	1	2	3	4	5	6	7	8	9	Prop.
24	38021	38202	38382	38561	38739	38917	39094	39270	39445	39620	177
25	39794	39967	40140	40312	40483	40564	40824	40993	41162	41330	170
26	41497	41664	41130	41996	42160	42325	42440	42651	42813	42975	164
27	43136	43297	43457	43616	43775	43933	44091	44248	44404	44560	158
28	44716	44871	45025	45179	45332	45484	45637	45788	45939	46090	153
29	46240	46389	46538	46687	46835	46982	47129	47276	47442	47567	148
30	47712	47857	48001	48144	42297	48430	48572	48714	48855	48996	143
31	49136	49276	49415	49554	49693	49831	49969	50106	50243	50379	138
32	50515	50651	50786	50920	51055	51189	51322	51455	51587	51720	134
33	51851	58983	52114	52244	52375	52504	52634	54763	52892	53020	130
34	53148	53275	53403	53529	53656	53782	53908	54033	54158	54283	126
35	54407	54531	54654	54777	54900	55023	55145	55267	55388	55509	122
36	55630	55751	55871	55991	56110	56229	56348	56467	56585	56703	119
37	56820	56937	57054	57171	57287	57403	57519	57634	57749	57874	116
38	57978	58093	58206	58320	58433	58546	58659	58771	58883	58995	113

No.	0	1	2	3	4	5	6	7	8	9	Prop.
39	59106	59218	59329	59439	59550	59660	59770	59879	59988	60097	110
40	60206	60314	60423	60531	60638	60746	60853	60959	61066	61172	107
41	61278	61384	61490	61595	61700	61805	61909	62014	62118	62221	104
42	62325	62428	62531	62634	62737	62839	62941	63043	63144	63246	102
43	63347	63448	63548	63649	63749	63849	63949	64048	64147	64246	99
44	64345	64444	64542	64640	64738	64836	64933	65031	65128	65225	98
45	65321	65418	65514	65610	65706	65801	65896	65992	66087	66181	96
46	66276	66370	66464	66558	66652	66745	66839	66932	67025	67117	95
47	67210	67302	67394	67486	67578	67669	67761	67852	67943	68034	92
48	68124	68215	68305	68395	68485	68574	68664	68753	68842	68931	90
49	69020	69108	69197	69285	69373	69461	69548	69636	69723	69810	88
50	69897	69984	70070	70157	70243	70329	70415	70501	70586	70672	86
51	70757	70842	70927	71012	71096	71181	71265	71349	71433	71517	84
52	71600	71684	71767	71850	71933	72016	72099	72181	72263	72346	82
53	72428	72509	72521	72673	72754	72835	72916	72997	73078	73159	81

Logarithms of Numbers from 54 to 68—*continued.*

No.	0	1	2	3	4	5	6	7	8	9	Prop.
54	73239	73320	73400	73480	73560	73640	73719	73799	73878	73957	80
55	74036	74115	74194	74273	74351	74429	74507	74586	74663	74741	78
56	74819	74896	74974	75051	75128	75205	75282	75358	75435	75511	77
57	75587	75664	75740	75815	75891	75967	76042	76118	76193	76268	75
58	76343	76418	76492	76567	76641	76716	76790	76864	76938	77012	74
59	77085	77159	77232	77305	77379	77452	77525	77597	77670	77743	73
60	77815	77887	77960	78032	78104	78176	78247	78319	78390	78462	72
61	78533	78604	78675	78746	78817	78888	78958	79029	79099	79169	71
62	79239	79309	79379	79449	79518	79588	79657	79727	79796	79865	70
63	79934	80003	80072	80140	80209	80277	80346	80414	80482	80550	69
64	80618	80686	80754	80821	80889	80956	81023	81090	81 58	81224	68
65	81291	81358	81425	81491	81558	81624	81690	81757	81823	81889	67
66	81954	82020	82086	82151	82217	82282	82347	82413	82478	82543	66
67	82607	82672	82737	82802	82866	82930	82995	83059	83123	83187	64
68	83251	83315	83378	83442	83506	83569	83632	83696	83759	83822	63

LOGARITHMS OF NUMBERS FROM 69 TO 83—*continued.*

No.	0	1	2	3	4	5	6	7	8	9	Prop.
69	83885	83948	84011	84073	84136	84198	84261	84323	84386	84448	63
70	84510	84572	84634	84696	84757	84819	84880	84942	85003	85065	62
71	85126	85187	85248	85309	85370	85431	85491	85552	85612	85673	61
72	85733	85794	85854	85914	85974	86034	86094	86153	86213	86273	60
73	86332	86392	86451	86510	86570	86629	86688	86747	86806	86864	59
74	86923	86982	87040	87099	87157	87216	87274	87332	87390	87448	58
75	87506	87564	87622	87680	87737	87795	87852	87910	87967	88024	57
76	88081	88138	88196	88252	88309	88366	88423	88480	88536	88593	57
77	88649	88705	88762	88818	88874	88930	88986	89042	89098	89154	56
78	89209	89265	89321	89376	89432	89487	89542	89597	89653	89708	55
79	89763	89818	89873	89927	89982	90037	90091	90146	90200	90255	54
80	90309	90363	90417	90472	90526	90580	90634	90687	90741	90795	54
81	90849	90902	90956	91009	91062	91116	91169	91222	91275	91328	53
82	91381	91434	91487	91540	91593	91645	91698	91751	91803	91855	53
83	91908	91960	92012	92065	92117	92169	92221	92273	92324	92376	52

Logarithms of Numbers from 84 to 99—*continued.*

No.	0	1	2	3	4	5	6	7	8	9	Prop.
84	92428	92480	92531	92583	92634	92686	92737	92788	92840	92891	51
85	92942	92993	93044	93095	93146	93197	93247	93298	93349	93399	51
86	93450	93500	93551	93601	93651	93702	93752	93802	93852	93902	50
87	93952	94002	94052	94101	94151	94201	94250	94300	94349	94399	49
88	94448	94498	94547	94596	94645	94694	94743	94792	94841	94890	49
89	94939	94988	95036	95085	95134	95182	95231	95279	95328	95376	48
90	95424	95472	95521	95569	95617	95665	95713	95761	95809	95856	48
91	95904	95952	95999	96047	96095	96142	96190	96237	96284	96332	48
92	96379	96426	96473	96520	96567	96614	96661	96708	96755	96802	47
93	96848	96895	96942	96988	97035	97081	97128	97174	97220	97267	47
94	97313	97359	97405	97451	97497	97543	97589	97635	97681	97727	46
95	97772	97818	97864	97909	97955	98000	98046	98091	98137	98182	46
96	98227	98272	98318	98363	98408	98453	98498	98543	98588	98632	45
97	98677	98722	98767	98811	98856	98900	98945	98989	99034	99078	45
98	99123	99167	99211	99255	99300	99344	99388	99432	99476	99520	44
99	99564	99607	99651	99695	99739	99782	99826	99870	99913	99957	44

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